SCIENCE FOR TODAY

Philps

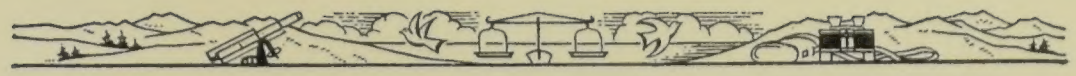
R. A Philps

NAME OF PUPIL

Class..... Room..... Year.....

Fire Precaution 184

Many branches of science are included in general science. Will science continue to discover more and more about what is beyond, upon, and within the earth?



SCIENCE FOR TODAY

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PREFACE

The steady progress of science requires corresponding changes in the content of a science textbook. During the past few years the development of new ideas in science teaching and continued experiments in the schools have constantly been directed toward further improvements in the use of science in education. *Science for Today* incorporates the distinctive elements of the authors' earlier *Introduction to Science* and in addition contains many new features that have been proved by classroom experience to be effective.

This book, like *Biology for Today*, with which it forms a two-volume series, is organized throughout in accordance with the energy concept. The content was determined by years of classroom experience and an extensive investigation of the content of general science,[1] these supplemented also with topics from the *New York State Syllabus in General Science* and from other important and authoritative syllabi. A large number of state and city syllabi have been carefully studied as checks on the essential content of the course in general science.

The topics of greatest importance are designated by asterisks. These topics should be included among the minimal essentials in any plan of instruction the teacher of general science may adopt.

The organization of this book is simple and lends itself readily to any coherent plan of instruction. There are fifteen large units, each dealing with some fundamentally important aspect of science in its relation to energy. Each unit is divided into a small number of chapters, and each chapter is divided into a small number of problems. Each unit is introduced by a preview which presents the major problems discussed in the unit. Each of the chapters

[1] Francis D. Curtis, *A Synthesis and Evaluation of Subject-Matter Topics in General Science*, Ginn and Company, Boston, 1929. This study combines and evaluates the topics revealed in fifteen investigations of the content of general science and three city syllabi of general science.

composing the unit is introduced by "Questions this Chapter Answers," which provide a more detailed orientation in the unit. Chapter I serves as an introduction to the entire course.

Especial emphasis is given to the development of the principles and the fundamental generalizations of science and to establishing scientific attitudes in accordance with the most authoritative recent recommendations.[1] Special attention is also given to affording abundant training in the various elements of scientific method. To these ends many exercises on major generalizations, scientific attitudes, scientific principles, and scientific method are included in the experiments, in the legends of illustrations, in the special exercises at the ends of chapters, and in the projects. Many additional experiments and projects are included in the *Workbook to accompany Science for Today.*

The ability of a pupil to comprehend a textbook readily depends chiefly on such factors as the interest and appeal of the material studied, the simplicity of vocabulary, and the clarity of style. One of the authors [2] has conducted research over several years to determine what vocabulary is appropriate for students of general science. This investigation represents experimentation with several hundred pupils in a considerable number of widely distributed schools. The results of this study indicate that the difficulty of comprehension of nonscientific words increases greatly for pupils of general science with the seventh-thousand "level" of Thorndike's *Teachers' Word Book of 20,000 Words*; also, that the sixth-thousand level is difficult as compared with the preceding levels. Consequently the authors have limited the nonscientific vocabulary of this book chiefly to the six thousand words in the English language which are most frequently used. When other words are used, each is defined and pronounced in a way that has proved effective. Defined words are repeated at several points in the text in order to provide the necessary drill in their proper use.

[1] Committee of the National Society for the Study of Education on the Teaching of Science, *The Thirty-first Yearbook of the National Society for the Study of Education*, Part I. Public School Publishing Co., Bloomington, Illinois, 1932.

[2] Francis D. Curtis, "A Study of the Vocabulary Comprehension of Pupils Studying High School Science" (unpublished study).

Although relatively few textbooks of general science include glossaries, the authors' experience and the opinions of many other teachers have led to the conclusion that the glossary is an indispensable aid to effective teaching of general science. In order to insure that this textbook as well as its Glossary shall contain the proper scientific terms, an investigation[1] has been made resulting in a list of scientific terms. This list includes not only those terms most frequently found in glossaries already published, but also a large number of terms which subject-matter experts and experienced teachers of general science regard as most essential. References to the Glossary are included in the text in order to motivate the pupils in acquiring the useful habit of making regular use of the Glossary.

Self-tests on comprehension of essential subject matter are found at the ends of the problems. These frequent tests provide constant checks on mastery of essential subject matter. More extensive tests are provided in the *Tests to accompany Science for Today.*

Abundant provision for individual differences will be found (1) in the wide and varied selection of materials discussed, of which the minimal essentials are indicated; (2) in special reports offering a wide range of difficulty; (3) in many kinds of questions and problems presented in the legends of the illustrations and at the ends of chapters[2]; and (4) in the experiments and projects. Additional experiments and projects are included in the *Workbook to accompany Science for Today.*

The increasing emphasis upon education for worthy use of leisure, as well as the need for providing for individual differences, has led the authors to provide an entire unit (Unit XV) consisting of scientific activities for out-of-school hours.

THE AUTHORS

[1] Francis D. Curtis and Lorne P. Adams, "A Study of the Glossaries of Textbooks of General Science" (unpublished study).

[2] These questions, together with the "Self-tests" at the end of each problem and the "Problems" at the end of each chapter, are discussed in the *Teachers' Manual.*

ACKNOWLEDGMENTS

It is impossible to acknowledge individually all who have contributed toward this new book. The authors wish, however, to make grateful acknowledgment of valuable criticisms and suggestions received from many teachers who have been using *Introduction to Science* in their classrooms. They wish also especially to acknowledge help from those specialists in subject matter and in the teaching of science who read critically portions of the manuscript: Professors W. Carl Rufus, Irving D. Scott, Henry H. Higbie, and Marshall L. Byrn of the University of Michigan for suggestions for the improvement of the sections dealing respectively with astronomy, geology, light, and automobile mechanics; to Professor Martin L. Robertson of New York University and Professor Gerald W. Fox of Iowa State College for assistance with the material on radio and television; to Mr. William S. Carlson for constructive criticism of the unit on geology; to experts with the Detroit Edison Company and the Michigan Bell Telephone Company for their critical reading of the materials dealing with electricity and communication; to Mr. William T. Wyman of Central High School, Providence, R.I., for valuable suggestions in the preparation of the chapters on electricity; and to Mr. Weslie C. Darling and Mrs. Nina Henry Sherman of the University of Michigan High School for critical reading of the entire manuscript.

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TO THE STUDENT

Suggestions for Effective Study

Interesting examples and applications of scientific principles may be seen everywhere. You may gain profit and pleasure from studying these and from your own experience in any one of many aspects of science. If you cultivate the habit of careful and accurate observation both inside and outside the laboratory, it will pay large returns in the knowledge gained. Be alert to find illustrations and applications of the scientific principles and laws to which you will be introduced as this course proceeds. Try to use scientific methods and scientific attitudes in the ways in which these are illustrated in this study of general science.

Until you have gained considerable scientific experience, you will probably get most of your help from your textbook and your teacher. The suggestions for study which are given here are the ones which many students of science have found helpful.

Your textbook is organized into a few large units so that you may think of science in terms of its largest divisions and principles. Your problem is somewhat like that of a pioneer in a strange country. He climbs a hill or a tree to get a general idea of the surrounding country and to locate the principal landmarks. In a similar way you may get a general idea of the unit and may learn what are its chief problems. In beginning a unit, read "Problems Discussed in this Unit." Recall what you already know about these major problems. Turn through the unit, noting the titles of the chapters. Then in the first chapter of the unit read "Questions this Chapter Answers," noting which ones you think you can answer completely, which partly, and which not at all. Turn through the chapter, noting its minor problems. When you have gained a good general idea of what the unit discusses and the problems of the first chapter of the unit, you will be ready to take up the study of the day's assignment. The

remaining chapters of the unit should be attacked in the same way. You will find the following study methods helpful:

1. First read the entire assignment through rapidly. Then, with its main points in mind, read the assignment again carefully, paragraph by paragraph, for a more accurate and detailed knowledge of what it contains. Train yourself to get the essential ideas and facts of each paragraph with only this second reading. There should be little or no difference between reading a text and studying it.

2. Each chapter is composed of sections of one or more paragraphs which deal with the topic that is suggested in the section title. In your second reading, read very carefully, then close the book and try to state the most important ideas in the paragraph or paragraphs you have just read. It is not desirable to try to remember or to repeat the exact words of the book. It is far better to remember the ideas which the passage presents and to restate these in your own words. At first you may not be able to do this with a single careful reading, though you should try to make one reading serve. It will be possible soon to train yourself to master a short section in a single careful reading.

3. As you read a paragraph try to find a key sentence, that is, one sentence which indicates better than any other what the whole paragraph is about. Often this sentence will be the first one in the paragraph. For example, the key sentence in each of the first two paragraphs of Chapter I is the first sentence of the paragraph. Sometimes the key sentence is the last one, as, for example, "It is not certain that any faucet filter yet invented makes polluted water sufficiently pure for drinking" (p. 89). *If the book is your own*, it is good practice to draw a line under each key sentence. Having them thus marked will be of great help to you both in fixing the idea in mind and in later review.

4. After you have read a paragraph, close your book and try to make in a single sentence a summary of the most important ideas of the paragraph. Of course the length of this sentence will vary with the material and the length of the paragraph, but twenty words is a convenient limit to set yourself. Fewer words will often be enough. For example, the paragraph beginning with "What is science?" (p. 5) can be summarized by this sentence:

"Science consists both of collecting facts by observing and experimenting and of organizing these facts."

If the book belongs to you, it is good practice for you to write your sentence summary of it in the margin, beside the paragraph. This practice will help you to remember the important thought, and will also help in reviewing.

5. After you have read a paragraph, write a few questions the answers to which you think are important and which you think any student who has read the same paragraph should be able to answer. Try to make these questions tests of the application of facts rather than the mere recall of the facts themselves. Here are two good questions which require not the mere knowledge of facts but an application of them: "What facts about the atmosphere would be valuable for an aviator to know?" (Page 18.) "What kinds of facts could be learned from sending up self-recording instruments attached to balloons?" (Page 18.) Under the illustrations and at the ends of the chapters, there are about forty different kinds of questions. Try to make a number of different kinds of clear, meaningful questions which are real tests of what one should learn from his reading.

6. Always study an illustration at the point where it is referred to in the text. Only in this way can you get the most benefit from the illustrations. Additional facts, questions, or problems are included in most of the legends under the illustrations. Try to answer these questions or solve these problems.

7. Few students are able to give a good discussion of a topic. Too often, when asked to discuss, the student merely tells everything he can remember about the topic, giving the facts in a disconnected way as they occur to him. You can train yourself to make good discussions by learning to follow this simple outline of questions, answering each as you come to it:

What is it? (Start with a definition or a short description of the object or process you are discussing.)
What is its history? — if its history is important.
Where is it found? or Where does it occur?
What are its most important characteristics, those which distinguish it from everything else?
What can it do?
What is its relation, if any, to man?

Not every topic, of course, will entirely fit this outline. Omit the questions which are not appropriate, and add others that you regard as appropriate.

8. Comparing one animal, plant, machine, process, or law with another is a valuable way of learning and remembering important facts and principles. A good comparison includes both those respects in which things are alike and those respects in which they are different. Therefore write first all the similar characteristics of whatever you are comparing. In a separate column write all the respects in which they are different. Then select from the two columns the points which you think are of most importance.

9. The successful student usually reviews his material frequently and thoroughly. At the ends of the problems within the chapters are tests which will aid not only in testing yourself to see whether you have mastered the materials but also in reviewing the materials. *Do not write the answers to the test questions in your book,* since such practice will rob them of most of their value for later reviews, when you will want to test your memory and re-read parts which you may have forgotten.

10. After you have completed the study of a chapter, turn again to "Questions this Chapter Answers." If you cannot now answer all these questions, review the chapter until you can. After you have completed the study of any unit, turn back to the introduction to the unit. Re-read it. Change each of the large unit problems into a complete statement. Then, using these statements as major headings, write under each, in your notebook or in the Workbook at the place indicated, complete statements which further explain, or give proof of, each problem presented. You may be able also to organize the problems and your statements in the form of an outline.

11. In making a comparison or a discussion, in reviewing, or in summarizing a unit, use any knowledge or experience you have had, whether gained in school or out of school.

SCIENCE FOR TODAY

FIG. 1. Science and progress. Can you explain this figure?

Chapter I · How Knowledge Grows

Science then and now. Ages ago, thousands of years before the dawn of history, the earliest human beings are thought to have lived in some of the warmer regions of the earth. These ancient men wore no clothing, and consequently had to depend on the energy of the sun for warmth. They found food wherever they could — fruits, nuts, leaves, and roots of plants, and such animals as they could capture with hands and possibly with teeth. These first human beings ate their food raw, since they knew nothing about the use of fire.

During hundreds of centuries these ancient people were slowly learning how to use some of the things about them in order to live more safely and comfortably. The hard-earned knowledge which they gained from experience, and the crude applications they were able to make of this knowledge, were the beginnings of science. They learned to use the skins of animals for clothing to keep them warm. Much later they found how to make and use fire, so that they no longer needed to depend entirely on the sun for light and heat. At length they discovered how to grow a few food plants, but they were hunters for thousands of years before they began to be farmers. They learned to tame animals and to use some of them in cultivating their crude fields, in carrying burdens, and in doing other work. Also during these ages ancient men were learning to make simple weapons, shelters, and implements of various sorts. The earliest of these man-made things were of wood, stone, or bone; later ones were of bronze[1] and still later ones of iron.

We can be fairly certain of the stages of human progress for only the short period of the last five or six thousand years, during which there has been recorded history. For the preceding ages, before there were any historical records, scientists[2] can only piece together scattered bits of information (Fig. 1). These have been gained from relics and other bits of evidence of primitive[3] men

[1] *Bronze:* a metal made by melting together copper and tin.

[2] *Scientist* (si'en tist): one who makes a study of science.

[3] *Primitive* (prim'i tiv): having to do with the beginning.

FIG. 2. When your grandfather was your age could he have known of any of these scientific inventions? Can you name any new applications of science which have come into use in your own lifetime?

which have been found in the earth and in caves. The order in which important discoveries and inventions were made is not yet known and may never be known. It is certain, however, that as the centuries passed, men made slow but continued progress in improving their ways of living through the discovery and use of scientific facts. Many thousand years passed before they learned how to use the energy of the wind to drive boats, and the energy of running water to turn the wheels of crude mills and to perform other needed services.

Progress in the use of science has been more and more rapid the nearer the approach to the present day. The numbers of new inventions and of improvements of older ones have increased at a rapid rate. New sources of energy and new ways of using these sources have made our modern civilization what it is. Thus, during the lives of men and women now living, scientists have learned to use the energy of gasoline to drive automobiles and airplanes, and to use electricity for lighting, heating, transportation, and communication (Fig. 2).

What is science? When we hear the word *science* we are likely to think of some wonderful application of science such as the radio, the airplane, or talking pictures. Or we may think of science as something remote and mysterious or hard to understand. But science is everywhere about us. The great scientific discoveries and inventions are the final results of combining many simple discoveries and inventions. For example, many parts of the latest model of an automobile are made up of simple machines some of which were discovered by primitive men ages ago. Kerosene lamps, which are still widely used in this country, are the more improved forms of cruder oil lamps which were common centuries before the time of Christ. Scientific knowledge is made up of the facts which people learn by observing and experimenting with the things about them in their environment. Then the great scientists put related facts together in an orderly way, making this increasing knowledge clearer and easier to use.

*[1] Our study of science will be concerned with the various materials and objects in our environment and with the nature and use of energy. Some of these materials and objects are living and some are not. Some we can see and handle easily and some are invisible. Some possess energy and some do not. Those which have energy are either moving or are able to move or to cause something else to move (Fig. 3). In the chapters that follow we shall learn many facts about energy and the principles relating to it.

You can become a scientist. Perhaps you have visited a great laboratory[2] full of strange and interesting apparatus.[3] If you have not, you may have seen the science laboratories of your school and may have examined some of the apparatus used in the study of chemistry, physics, or biology. You may have concluded that it is necessary to have and use apparatus in order to be a scientist. This is not always true, though most of the great scientists need laboratories and complex[4] apparatus for their experimenting. You

[1] To the Teacher. The paragraphs marked with an asterisk contain the materials which research has indicated as being of major importance. Suggestions for effective use of these materials will be found in the *Teachers' Manual.*

[2] *Laboratory* (lab'o ra to ry): a place where scientists work.

[3] *Apparatus* (ap a ra'tus): the bottles, dishes, scales, machines, and similar things which scientists use in experimenting.

[4] *Complex* (kom plex'): the opposite of simple.

FIG. 3. How many examples of different things which possess energy can you see in these pictures?

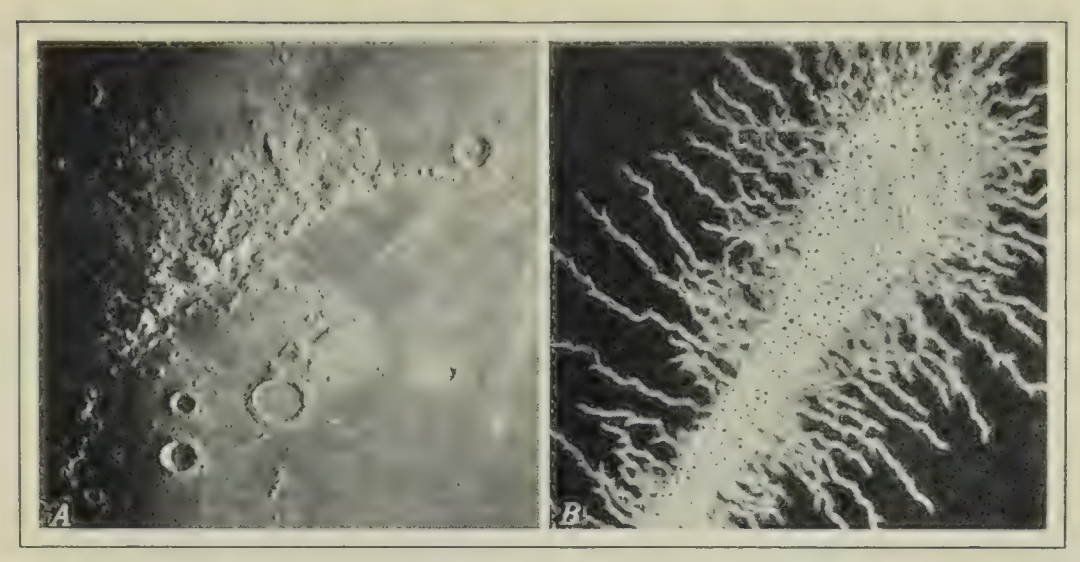

FIG. 4. Extending and exploring our environment. *A*, sunset on northern portion of the moon as photographed through a telescope; *B*, molds and bacteria which grew in a fly's footprint, as photographed through a microscope.[1] How can we extend our environment by using the automobile and the radio? How many other scientific inventions can you name which help us to explore and extend our environment[2]?

can train yourself to be a scientist by always looking for questions and problems in your environment, by trying to solve these problems by observing and experimenting in careful ways, and by studying the ways in which scientists solve problems (Fig. 4).

Not every high-school student can expect to become a great scientist, whose discoveries add to the beauty, understanding, and comfort of the whole world. Every student, however, can add greatly to his or her own pleasure and information by cultivating habits of observing carefully and of experimenting to learn new facts. A few may really become great scientists.

You can find scientific problems everywhere in your environment. Develop the habit of looking for them on your way to and from school, or wherever you go or happen to be. Search for these problems and try to solve them by observing with your eyes,

[1] *A*, courtesy of Mt. Wilson Observatory; *B*, from "Secrets of Nature," Educational Department, British Educational Films, Ltd.

[2] *Environment* (en vi'ron ment): all the surroundings and conditions among which we live make up our environment. Air, water, food, light, heat, sound, soil, animals, plants, and people are some of the chief factors of our environment. Some other factors (that is, things which influence us) in our environment are houses, automobiles, electric lights, books, magazines, and newspapers.

"I wonder what started that new rattle."
"What bird is that?"
"Which flower has that peculiar fragrance?"
"No wonder this room is cold."

FIG. 5. What sense is being used in each of these pictures in locating problems and in observing?

your ears, and all your other senses, for a scientist trains himself to observe with all his senses (Fig. 5). Some of these problems you will already be able to answer. Some you will be able to solve by further observation, clear and careful thinking, and careful experimenting. Some you will be unable to solve. And some perhaps nobody will be able to solve for many years to come, if ever.

How a scientist experiments. In inventing and improving the electric lamp Edison experimented with the fibers of many kinds of palm trees, as well as with many other substances, before he found a satisfactory substance for the small wire within the globe. He also performed about nine thousand experiments before he completed his invention of the Edison storage cell. The Wright brothers performed hundreds of experiments with their airplanes before they succeeded in making a model in which one of them could fly. The *experiments* performed by Edison and the Wrights

were of course very different. Yet the *method* used by these and all other great scientists in performing an experiment is essentially the same. A scientist uses five steps in performing an experiment: (1) he makes sure of what the *problem* or question is; (2) he decides what *procedure* or method he will use in trying to find the answer to the problem; (3) he selects the *materials* to be used in trying to find the answer to the problem; (4) he records the *observations* which he makes while carrying out the procedure; and (5) from his observations he makes his *conclusion* or answer to the problem.[1]

These five steps can be illustrated with a problem of the kind which students of general science find and try to solve. For example, suppose you were curious to know whether a quart of milk weighs more or less than a quart of water. First you state your *problem* very clearly as a question: "Does a quart of milk weigh more than, less than, or the same as a quart of water?"

Next you select the *materials* needed for carrying out your *procedure*: a quart bottle entirely full of milk; scales; an empty quart bottle.

You then begin your *procedure* and *observations*: First carefully weigh the bottle of milk and record its weight in pounds and ounces. Then pour the milk into the second bottle and thoroughly rinse the first bottle with water until you are certain that you have removed all the milk. Then fill the bottle with water to exactly the same level to which the milk filled it before. Wipe the outside of the bottle carefully to remove any water there may be on it. Now carefully weigh the bottle of water and record the weight under the weight of the same bottle full of milk. Since you have used the same bottle for both parts of the experiment, any difference in the weights you may find will indicate which is the heavier liquid.

You are now ready to draw your *conclusions* in the form of a statement which answers the question in your problem.

How a scientist thinks and acts. If you are to become a scientist it is not enough that you learn and practice scientific methods

[1] Throughout this book many exercises on methods which scientists use in their investigations are illustrated in connection with suggested experiments. These methods include those used in locating problems; making hypotheses or generalizations from given facts; recognizing errors and defects in the conditions or experiments described; evaluating data or procedures; evaluating conclusions in the light of the facts or observations upon which they are based; planning and making new observations to find out whether certain conclusions are correct; making inferences from facts and observations; inventing check experiments; using controls; isolating the experimental factor.

Cram and Ferguson

FIG. 6. Cathedral of St. John the Divine in New York City, as it will look when completed. The construction of this cathedral was begun in 1892 and is still in progress. It is expected to be completed about 1945. What scientific attitudes did those who planned it need to have? Why is exact measurement necessary in such a plan?

in your observation of phenomena,[1] in your search for problems, and in solving them. You must also develop the scientific attitudes. A list of scientific attitudes should include those on pages 12 and 13. The units of science in this book will afford many opportunities to acquire scientific attitudes.

Science depends on accurate measuring. Much of the progress which scientists have made in controlling and improving the environment has become possible because they have been learning to measure with great accuracy. Some examples will illustrate this statement. The great blocks of stone of which the stately Cathedral of St. John the Divine (Fig. 6) is being constructed have all had to be shipped from a considerable distance. The largest of these blocks weigh many tons. So accurately are they cut and sized at the quarry that when assembled on the site of the cathedral, they require no further hewing or shaping. When the Moffat Tunnel in Colorado was constructed, digging began

[1] *Phenomenon* (fe nom'e non); plural, *phenomena*: *any* happening is a phenomenon.

at both ends at once. When at length the two excavations[1] met inside the mountain, about three miles from either end of the tunnel, the two ends joined almost exactly. For the study of light a machine has been invented by means of which thirty thousand exactly parallel lines can be cut in the space of an inch on a glass plate. There are machines with which you could measure distances shorter than the thickness of this page. In every well-equipped chemical[2] laboratory there are scales so accurate that you could weigh a pencil mark with them. These and many other examples which might be cited prove the statement that the wonders of modern engineering,[3] mechanics,[4] and other branches of science would be impossible without extreme accuracy in measurement.

Science depends also on the right use of imagination. The great canals, the wonderful bridges and tunnels, the beautiful ocean steamships, the high buildings, each existed first in someone's imagination. But more than imagination is necessary. These statements can be illustrated by the building of the Panama Canal. The construction of this canal, the greatest in the world, was not merely the difficult task of digging, through country much of which was rocky and mountainous, a ditch large enough so that ships might pass through it between the Pacific Ocean and the Caribbean Sea. It demanded also that there be at each end a harbor protected with sea walls and provided with docks, fuel plants, repair shops, and all other things needed for shipping. The problem of providing these necessities and other problems just as difficult had to be solved first in the minds of the engineer in charge, Colonel Goethals, and his assistant engineers. Such feats of science, however, are possible only when imagination is combined with knowledge and use of materials, with scientific attitudes, and with exact measurements.

[1] *Excavate* (ex'ka vate) : to dig a hole or to uncover something buried in the earth. *Excavation* (ex ka va'shun) : act of excavating.

[2] *Chemical* (kem'i kl) : having to do with chemistry, which is the study of substances for the purpose of finding out what they are made of and how they act. A *chemist* is a scientist who knows and uses chemistry.

[3] *Engineering* (en ji neer'ing) : designing, planning, and constructing works such as buildings, railroads, canals, and the like.

[4] *Mechanics* (me kan'iks) : the science which deals with machines.

Scientific Attitudes

1

A scientist believes that nothing can happen without a cause.

2

A scientist does not believe in superstitions, such as charms or "signs" of good or bad "luck."

3

A scientist believes that occurrences which seem strange and mysterious can be explained finally by natural causes.

4

A scientist believes that truth never changes, but that our ideas of what is true change as we gain more and more knowledge.

5

A scientist is slow to accept as facts any statements that are not supported by convincing proof.

6

A scientist does not believe that there is necessarily any connection between two events merely because they occur at the same time (as in a coincidence).

7

A scientist is curious to know about his environment.

8

A scientist tries to be careful and accurate in all his observations and statements.

9

A scientist prefers, when possible, to do his own observing and experimenting. When it will help, he does not hesitate to use the results of other people's observations, when the evidence is good and when he knows that these others are scientists of established reputation.

10

A scientist patiently collects his facts by making his observations over as long a period of time as is necessary to solve his problem.

11

A scientist never bases final conclusions upon one or a few observations.

12

A scientist continues to hunt for satisfactory explanations of the phenomena he observes until he is convinced that he has found an explanation as nearly correct as the evidence permits. He is willing to change his conclusion if later evidence shows that his first conclusion is wrong.

13

A scientist does not express opinions or announce conclusions until he has considered the matter from all sides.

14

A scientist does not begin to experiment blindly and carelessly. He carefully plans to do his work in what seems, after careful thought, to be the best way.

15

A scientist considers for himself the evidence he hears and the facts he learns, and tries to decide whether they really relate to the matter which is being considered, whether they are sound and sensible, and whether they are complete enough to allow a conclusion to be made.

16

A scientist respects another's point of view. He is willing to be convinced by evidence. In other words, he would say: "I may be wrong in my beliefs, opinions, or conclusions. I will not change these without convincing evidence, but I shall always be willing to change if somebody shows me proof that I am wrong."

FIG. 7. "Both boys now examined the knife with care." Which of the ways of observing suggested on pages 7–8 and in Fig. 5, p. 8, are the boys using here?

ADDITIONAL EXERCISES AND ACTIVITIES

Exercise on Scientific Attitudes. 1. How many of the scientific attitudes can you discover in this story?

During one of their "hikes" not long ago two Boy Scouts stopped to cook their camp supper. One got his knife to cut kindling for the fire.

"Look, Jim, the little blade of my knife is all rusty, but the big one isn't at all."

He held up his knife to show the rust. Jim glanced at the knife without much interest.

Bob continued to stare at his knife. After a moment he said, "I wonder what made the little blade rust while the big one did not."

"Who cares?" said Jim. "Come on; let's hurry and get the fire started. I'm about starved."

"But I'd like to know how it happened," Bob protested, starting once more to cut kindling for the fire.

"Oh, well, it just happened that way. Strange things do just happen sometimes, you know."

"You know better than that, Jim. You know that nothing ever happens unless something makes it happen. Maybe the little blade rusted just because it is smaller than the big one."

"That's silly. If that were so, big steam engines wouldn't rust, and small iron things, like nails, would. And you know the engine in the old mill is rusted to pieces. Maybe the little blade isn't made of the same stuff as the big one."

"It is, though. Both of them say 'Eureka Steel' on them. Maybe something happened to the big one to keep it from rusting that didn't happen to the little one, or the other way around." Bob lighted the shavings under the small sticks, then piled the larger pieces loosely on top.

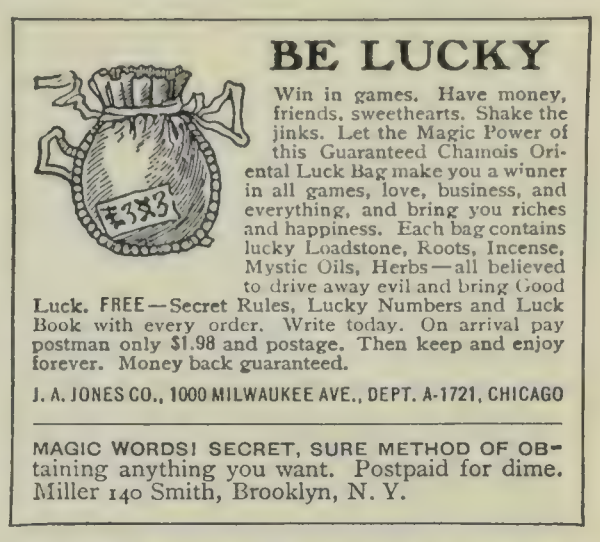
BE LUCKY
Win in games. Have money, friends, sweethearts. Shake the jinks. Let the Magic Power of this Guaranteed Chamois Oriental Luck Bag make you a winner in all games, love, business, and everything, and bring you riches and happiness. Each bag contains lucky Loadstone, Roots, Incense, Mystic Oils, Herbs—all believed to drive away evil and bring Good Luck. FREE—Secret Rules, Lucky Numbers and Luck Book with every order. Write today. On arrival pay postman only $1.98 and postage. Then keep and enjoy forever. Money back guaranteed.
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FIG. 8. Should you be glad if somebody made you a present of one of these? Why?

Jim picked up the knife and looked at it thoughtfully. "I've got it! Remember when we were over at the Big Woods last Wednesday you dropped your knife in the water. We were in a hurry, and you just shook the water from the knife without drying it. That's why it rusted."

"Yes; I guess that's why it rusted, all right; water does rust steel." Bob scratched his head thoughtfully. "But that doesn't tell us why the little blade rusted and the big one didn't. They were both wet."

Both boys now examined the knife with care (Fig. 7).

"Look, Jim, see this grease at the handle end of the big blade? Remember just before I dropped the knife into the water I was slicing bacon to fry? I used the big blade. So there was grease on the big blade and not on the little one. That's why the big blade didn't rust."

"That *sounds* all right. I know oil keeps things from rusting, but I don't know whether bacon fat does. Let's try it again and see. Today I'll cut the bacon with the *little* blade of *my* knife and not the big one. Then I'll drop it into the water just as you did, and then shake it off without drying it, just as you did, and we'll see what happens. It's an old knife; I don't care what happens to it, but both blades are bright now."

The boys did as Jim suggested, and a week later found that the big blade had rusted, while the little one had not.

2. The sort of advertising shown in Fig. 8 is often found in a certain type of magazine. Would a scientist buy the "Guaranteed Chamois Oriental Luck Bag" or the "Magic Words"? Justify your answer by quoting one or more of the scientific attitudes.

3. Make a list of all the superstitious beliefs and sayings you can think of, such as carrying a rabbit's foot for good luck, knocking on wood, "A four-leafed clover brings good luck," "Thirteen is unlucky," "Potatoes should be planted in the dark of the moon."

4. Which of the scientific attitudes were possessed by the primitive men discussed at the beginning of this chapter? Which of the attitudes tend to prevent (1) gossip; (2) slander; (3) belief in advertising claims in general; (4) belief that everything that is printed is true; (5) wearing "good-luck rings" for good luck; (6) belief in ghost stories?

5. After the following problem you will find five statements. See whether you can pick out the one which a carefully trained scientist would consider best. Then see whether you can find which of the scientific attitudes is illustrated by the problem and the best answer.

A new kind of fruit jar is advertised. A woman decides to give it a trial and buys one. The fruit she cans in it spoils, and she therefore concludes that the new jar is not a success.

a. There is no doubt whatever that she is right in her conclusions.

b. She is probably right, but perhaps she shouldn't decide after only one trial.

c. She is just about as likely to be wrong as she is to be right, because it isn't scientific to make a conclusion after only one trial, or experiment.

d. She is more likely to be wrong than right, because people do not advertise fruit jars or other things that are not first class.

e. She is probably wrong, because the jar in which fruit happens to spoil is "the exception that proves the rule."

6. A three-year-old boy is looking over a fence watching older boys playing football. If the fence is five feet high and the top of the little boy's head is one foot above the top of the fence, how tall is the boy? What is wrong with this problem?

Exercise on Scientific Method. What part of the story of the Boy Scouts illustrates each step of an experiment as described on page 9?

Exercise on Major Generalizations. What evidence from this chapter can you state which seems to you to prove these statements?

The world is very old.
Scientific knowledge grows slowly.

UNIT I · *The Air and Some of its Uses*

PROBLEMS DISCUSSED IN THIS UNIT

It is difficult for us to realize that the earth is completely surrounded by an "ocean of air" greater than any of the oceans of water, or than all of them together. This air, which we call the atmosphere, is as much a part of the earth as are the ground, the water, or anything else that is upon or beneath the surface of the earth. All the living things on the earth are in, or near the bottom of, this "ocean of air."

Though air is of very great importance, we are not ordinarily conscious of its presence unless the wind is blowing strongly enough to attract our attention. Without the air, however, our earth would be barren and silent, without life of any sort, and with extremes of temperature almost beyond our imagination.

In this unit we shall study some of the important problems which relate to the air. In later units we shall consider still other problems connected with the air and its uses. The important problems discussed in this unit are these:

What are some characteristics of the air?
What is the composition of the air?
How can the energy of air be used in doing work?
How can the energy of compressed air be used in doing work?

Chapter II · The Air, its Nature and Properties

Questions this Chapter Answers

What progress has been made in exploring the atmosphere?
Do soil and water contain air?
How did the barometer come to be invented, and how is it used in measuring atmospheric pressure?
What is the nature of the air and of some of the more important substances that compose it?

Problem II–A · What are Some Characteristics of the Air?

Exploring the atmosphere. Until recent times little has been known about the nature and extent of the atmosphere. Even today man has been able to explore it for only a few miles above the ground. Before the invention of balloons and airplanes investigations of the atmosphere had to be confined chiefly to observations made upon the earth's surface. By climbing mountains men gained some ideas about the air a few thousand feet above sea level. It was long known that as one ascends it becomes colder and also that upon high mountains it is harder to get enough air for breathing. It was early known, also, that the "ocean of air," unlike the oceans of water, has no surface. Nobody yet knows exactly how high above the earth the atmosphere extends. However, by means of observations made of "shooting stars," or meteors, it is estimated that the air surrounding the earth is at least two hundred miles deep. It is also believed that beyond the atmosphere there is only empty space, or vacuum. Some of the ablest scientists are now making a careful study of the energy that passes through the space outside the earth's atmosphere.

One method by which scientists have extended their knowledge of the atmosphere is by sending up small balloons, to which self-recording instruments are attached. Some of these balloons have risen to heights of more than twenty miles above the ground before they have burst and allowed the instruments to float down with a parachute.

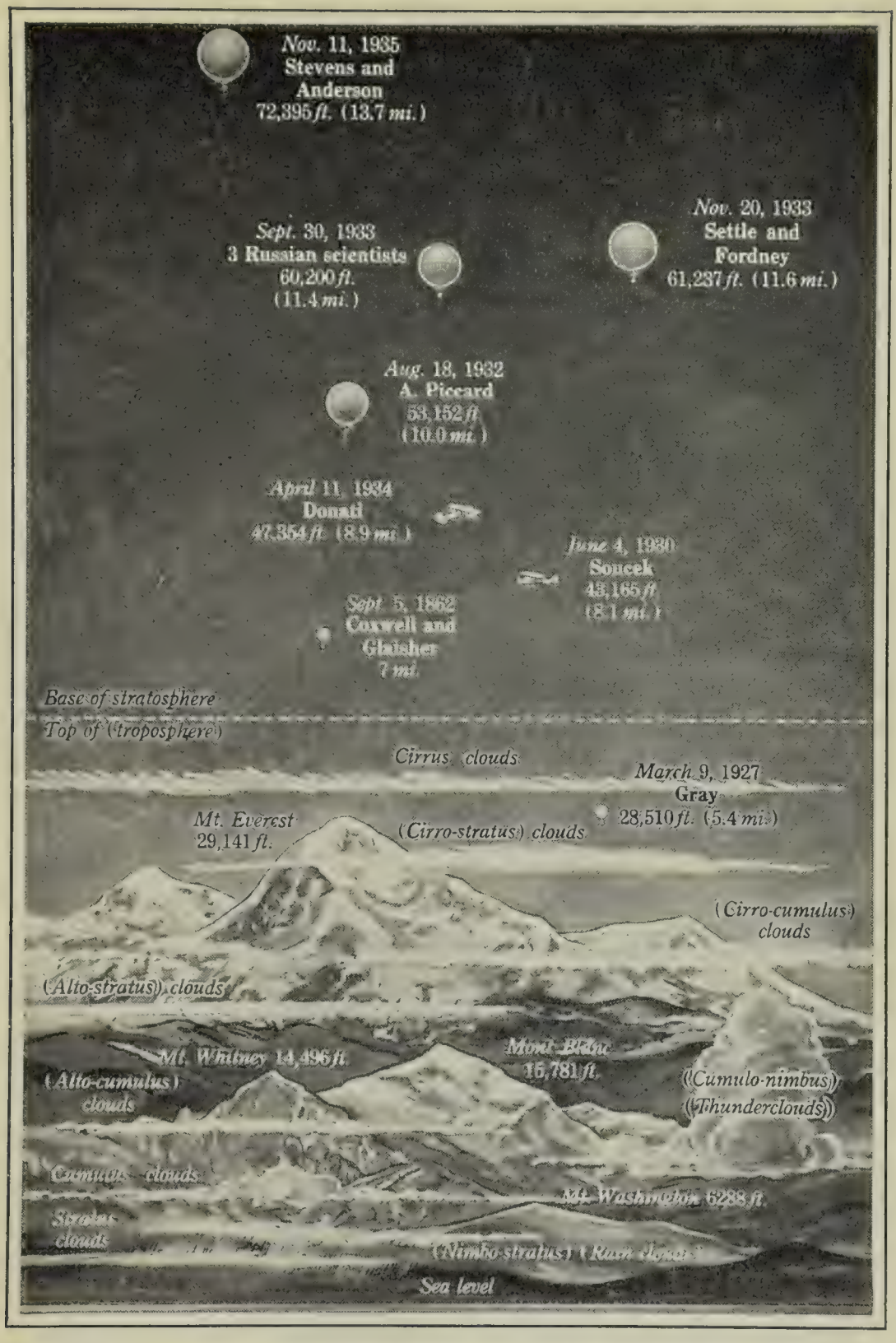

FIG. 9. Are there any winds at a height beyond the atmosphere? Explain. **Special Report:** Explorations of the stratosphere other than those included in this illustration. (Terms in parenthesis here and elsewhere are not intended as essential vocabulary but are included for pupils who may wish to learn and use a more extensive vocabulary)

Human beings have been able to go up several miles into the air. In 1862 two Englishmen, Coxwell and Glaisher, rose in an open balloon to a height of about seven miles. Glaisher became unconscious, and Coxwell, although unable to use his frostbitten hands, succeeded in opening the gas valve of the balloon with his teeth, thus permitting the balloon to descend and carry himself and his helpless companion to safety. Recently, riding in an airtight cabin in an airplane or in an airtight ball-shaped gondola suspended from a balloon, daring aviators have been able to ascend for a few miles into the stratosphere, which is the region of the atmosphere above rains, clouds, snow, and frost (Fig. 9). Scientific facts of great interest are being learned from such explorations into the stratosphere.

Is air all about us? It is a familiar fact that there is water in the soil beneath bodies of water such as streams, lakes, and oceans. It is perhaps less generally known that water finds its way into some rocks which do not appear to be porous.[1] Is it also true that there is air in the soil at the bottom of the atmospheric[2] ocean? Is it likewise true that air from the atmosphere enters the water of streams, lakes, and ponds? Some experiments will help to answer these questions.

Experiment 1. Is there air in soil? Put a lump of soil three or four inches thick into a vessel which contains enough water to cover the soil. What do you observe? Put into water lumps of various other kinds of soil. Do you secure the same results with each lump of soil? Answer with a complete sentence the question at the beginning of this experiment, and state one or more reasons for your answer.

Exercise on scientific method (using controls[3]). All the lumps of soil except the first one used served as controls. Of what use were these controls in this experiment?

Experiment 2. Is there air in water? Fill a pan or other vessel with as cold water as you can secure. Allow the vessel to remain in a warm room for twenty minutes or so. What do you observe? Answer with a complete sentence the question at the beginning of this experiment, and state one or more reasons for your answer.

[1] *Porous* (po'rus): full of pores, or holes, like bread or a sponge.

[2] *Atmospheric* (at mos fer'ik): having to do with the atmosphere.

[3] A control in an experiment is any part of the experiment which gives a basis for a comparison of results or for checking the accuracy of results.

Exercise on scientific method (using check experiments). If this experiment were repeated, the second experiment would serve as a check experiment. What would be the purpose of such a check experiment?

Does air exert[1] pressure? Anybody who has learned to dive knows that the water exerts pressure against his body. He also knows that this pressure becomes greater the deeper he dives. But it was not known until the seventeenth century that the air exerts pressure upon the surfaces of objects which it surrounds, as water does. The answer to this problem was secured as a result of a practical need. In 1640 the Duke of Tuscany dug a deep well and equipped it with a pump. To his disappointment, the pump would not lift the water to the top of the well, as had been expected. This was most surprising, because pumps had long been used as a means of lifting water from wells. It is true that the pumps had been used in wells in which the water rose to within about thirty feet or less from the top of the well. The Duke took his perplexing problem to Galileo.[2] Galileo was 76 years old and in such poor health that he could not undertake the Duke's assignment. He asked his pupil, Torricelli,[3] to see if he could find an explanation. Torricelli thought he would be able to explain the failure of the Duke's pump, provided he could prove that the atmosphere exerts pressure.

Torricelli's experiment. Since it would be difficult to experiment with a column of water 30 feet or more high, Torricelli decided to use mercury. He reasoned that if the atmospheric pressure were able to hold up a column of water, it should be able to support a column of mercury or any other liquid. He found that a certain volume of mercury is 13.6 times as heavy as is the same volume of water. He therefore decided that the atmospheric pressure ought to support a column of mercury about one thirteenth of 30 feet, or about $2\frac{1}{2}$ feet. To test this hypothesis[4] he performed an important experiment, which you can repeat.

[1] *Exert* (eg zurt'): to put in action a force or an ability.

[2] *Galileo* (gal i lay'o): an Italian scientist famous for his discoveries and inventions in the fields of mechanics and astronomy (1564–1642).

[3] *Torricelli* (tor re chel'le): a great Italian scientist (1608–1647).

[4] *Hypothesis* (hi poth'e sis): a scientist's attempt to tell, after he has been able to secure part of the facts, what will happen under certain conditions; his attempt to make an explanation which will fit the observed facts.

Experiment 3. Does the air exert pressure? If so, how long a column of mercury will it support in a tube? Seal one end of the tube in a flame. After the sealed end has cooled, fill the tube with mercury. It will be found easy to fill the tube by use of a medicine dropper so as to cause the mercury to run down one side of the opening. In this way air bubbles in the tube may be avoided. When the tube is *entirely* full of mercury, press one thumb tightly over the open end, then invert the tube in a dish of mercury. Be careful that none of the mercury escapes from the tube when you invert it, and keep your thumb tightly over the end of the tube until the open end is beneath the surface of the mercury in the dish. If you have been careful not to admit any air, there will now be above the mercury, in the closed end of the tube, an empty space, or vacuum,[1] where there is no air pressure. Measure the height of the column above the surface of mercury in the dish (Fig. 10). Answer with complete sentences the questions asked at the beginning of this experiment, and give a reason for your answer.

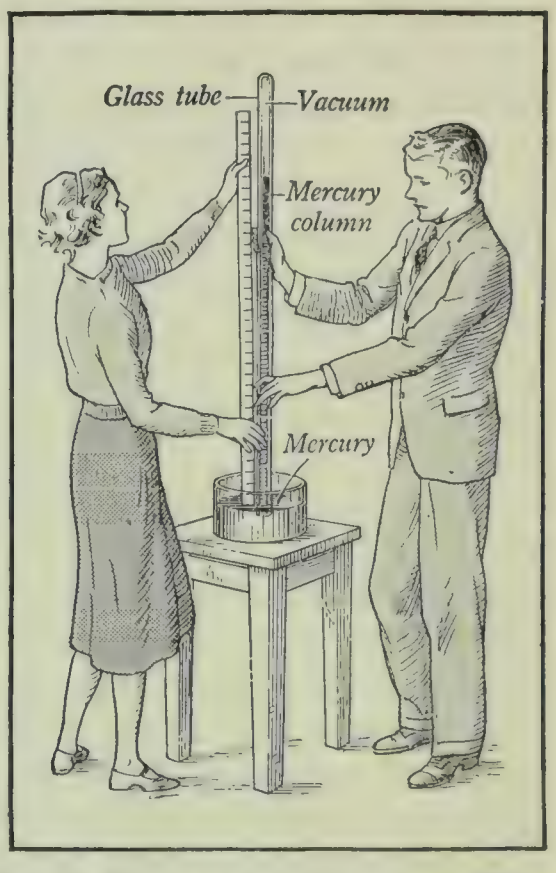

FIG. 10. Making a simple barometer. What supports the mercury column inside the tube that is inverted in the dish of mercury?

Having performed this experiment, Torricelli had the answer to his problem. He concluded that the water would not flow from the Duke of Tuscany's pump because the atmospheric pressure was not great enough to push water up the pump to the top of the well when the water level was more than about thirty feet below the ground level. He also concluded that the column of

[1] *Vacuum* (vak'u um) : a space that contains nothing whatever. *Partial vacuum:* a space in which the pressure of the air is less than the pressure of the air surrounding the space.

water about thirty feet high was exactly balanced by the weight of a column of air of the same diameter extending from the earth to the upper limits of the atmosphere (Fig. 11).

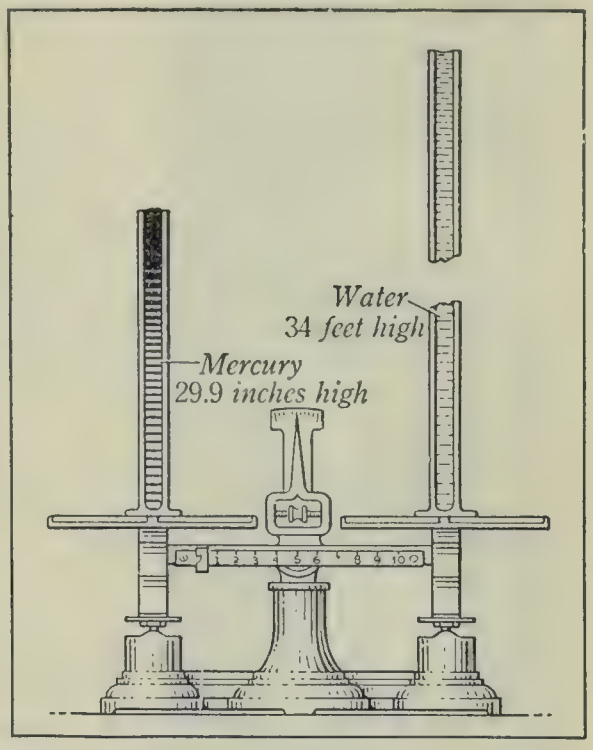

FIG. 11. A column of mercury 29.9 *inches* high weighs as much as a column of water of the same diameter 34 *feet* high or a column of air of the same diameter about 200 *miles* high. Why is one column shown as if it were broken?

How great is atmospheric pressure? Many later experiments by scientists have proved that at sea level the mercury always stands about thirty inches high in a barometer tube such as Torricelli used. It has been found, also, that a column of mercury thirty inches high and one square inch in cross section weighs 14.7 pounds, or nearly fifteen pounds. Therefore the atmospheric pressure at sea level is said to be about fifteen pounds per square inch. Thus we say that a pressure of fifteen pounds per square inch is one atmosphere of pressure or is a pressure of one atmosphere. Air pressures are frequently expressed in atmospheres.

Altitude and pressure. Air pressure varies at different altitudes, or heights above sea level. Experiments by Torricelli and other scientists established the fact that the height of the column of mercury in a barometer becomes less as one goes up a mountain or ascends toward the top of a high building. It was proved thus that the atmosphere is less dense and consequently exerts less pressure as the height above sea level is increased (Fig. 12). It was found that at three miles above sea level the barometer column is somewhat less than fifteen inches high. From this fact it is inferred that about half of all the air is below an altitude of three and one-half to four miles. Aviators have found that above three miles the air "thins out" very rapidly.

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FIG. 12. Can you explain this figure?

Modern types of barometers. The simple barometer which Torricelli invented was important in learning about air pressure, but it is not much used today. Much more convenient though less reliable forms of barometers which do not require the use of mercury have been invented. The most common type is the aneroid barometer (Fig. 13, *A* and *B*), which may be about as small as a watch. In place of a mercury column this type of barometer is equipped with a metal box from which part of the air was removed before the box was sealed. The changes between the atmospheric pressure outside the box and the pressure of the partial vacuum inside cause the top of the box to move up or down. These slight motions are increased by the arrangement shown in the figure, and are finally carried to a spool which turns an indicator, or pointer. This indicator moves over a dial on which the barometric[1] pressures are recorded. Such a barometer, called an altimeter, is carried on the instrument board of every airship. With it are tables showing the altitudes, or heights above sea level, which correspond to the various readings of the barometer. By this means the aviator may know how high he is flying at all times, even at night, when he is above the clouds, or when he is surrounded by fog.

[1] *Barometric* (bar o met'ric): having to do with a barometer.

Another type of aneroid barometer, called a barograph, gives a permanent record of air pressure (Fig. 13, *C*). It is equipped with

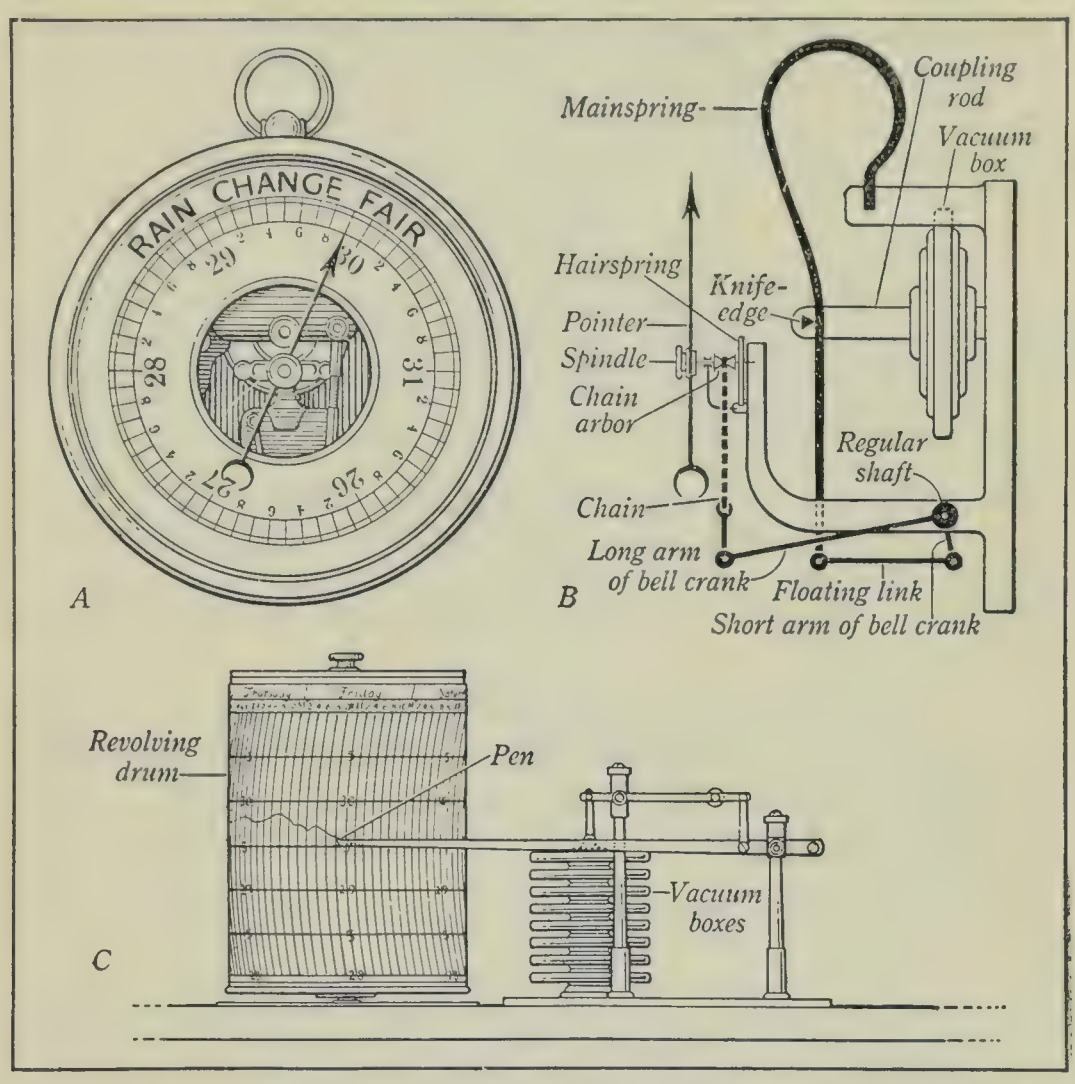


FIG. 13. *A*, front view of an aneroid barometer; *B*, diagram of the parts of an aneroid barometer; *C*, a barograph. The Weather Bureau uses the barograph. Why?

an indicator, or pointer, in the form of a pen which is constantly supplied with ink. The point of this pen rests upon a special record sheet on which are two scales, one for reading the barometer record and the other for recording the time of day. This record sheet is fastened around a cylinder which makes a complete revolution in twenty-four hours. The pen is placed on the paper at the point representing the hour at which the cylinder is started to revolve. As the cylinder slowly revolves, the pen marks a line on the paper, moving up or down as the changes in air pressure are

registered by the aneroid. The crooked line thus made is the day's record of its air-pressure changes.

Instructions for Taking the Tests. At the end of each problem you will find tests which will enable you to determine whether or not you know and can apply the important facts in the problem. You should be able to answer all these test items correctly. (*Do not write in the book.*) These tests will be of several types, but chiefly of the following three types:

1. *The Modified True-False Type.* In each of the items of this type one or more words are italicized. If the statement as given is not correct, make it so by changing one or more of the italicized words. Thus:

1. The Italian scientist who first used a mercury barometer in studying air pressure was *Torricelli.*

This statement is correct as given and needs no changes.

2. The Italian scientist who first used a mercury barometer in studying air pressure was *Galileo.*

This statement is not correct as given, but you can make it so by changing *Galileo* to *Torricelli.*

2. *The Completion Type.* Make each of the items of this type a complete and correct statement by supplying a word or phrase in the blank indicated by _ _(?)_ _. Thus:

The Italian scientist who first used a mercury barometer in studying the air was _ _(?)_ _

You can make this statement correct by adding the word *Torricelli* in the blank.

3. *The Modified Multiple-Response Type.* Each of the items of this type has five or more endings or parts. In some cases one of these will make the statement correct, while in other cases none of them will. If the correct one is given, select it. If the correct part or ending is not given, supply it. Thus:

1. The Italian scientist who first used the mercury barometer in studying air pressures was (1) Galileo; (2) Torricelli; (3) Copernicus; (4) Wright; (5) Edison.

The only one of the five endings which is correct here is (2) Torricelli.

2. The Italian scientist who first used the mercury barometer in studying air pressures was (1) Galileo; (2) Aristotle; (3) Copernicus; (4) Wright; (5) Edison.

None of these endings makes the statement correct. You would therefore need to supply the correct ending, Torricelli.

In some cases with this type of item there will be several endings each of which is more or less correct. In such cases you are expected to select the best answer.

The explanations of how to answer the other types of tests will be given with each type as it appears.

Self-test on Problem II–A. (*Do not write in the book.*) **1.** The atmosphere surrounding the earth is believed to be at least *three hundred miles* deep.

2. If a barometer could be carried beyond the atmosphere, its reading then would be __(?)__ inches.

3. A barometer would have a *higher* reading on a hill than in a mine.

4. *No* air is found in soil and water.

5. Normal atmospheric pressure, or pressure at sea level, is about (1) 10 inches of mercury; (2) 20 inches; (3) 25 inches; (4) 29 inches; (5) 34 inches.

6. An atmosphere of pressure is about __(?)__ pounds per square inch.

7. The *mercury* barometer is now used chiefly in place of the *aneroid* barometer.

Problem II–B · What Is the Air?

Early study of the nature of air. Before the time of Aristotle,[1] a famous Greek philosopher[2] who lived in the fourth century B.C.,[3] it was generally believed that air is a simple substance. Aristotle argued that air is not merely one substance but is a mixture of two, one of which he thought was moisture, the other he could not name. Unlike the earlier belief concerning the nature of air, Aristotle's conclusion was in part scientific, because it was based on his general observations of the formation of clouds and rain from the moisture in the atmosphere. Exact knowledge of the true nature of air began with the work of Priestley, an English scientist, in the seventeenth century.

***Composition of air.** Air is now known to be a mixture of many colorless gases. It is composed chiefly of nitrogen (about 78 per cent, or nearly four fifths), oxygen (about 21 per cent, or about one fifth), and argon (nearly 1 per cent) (Fig. 14). Air

[1] *Aristotle* (ar'is tot'l): one of the early writers about science (384–322 B.C.).

[2] *Philosopher* (fil os'o fer): one who devotes himself to a study of causes, reasons, or laws; he arrives at his conclusions through reasoning rather than through scientific experiments.

[3] *B.C.*: the first letters of "Before Christ," that is, before the birth of Christ.

contains very small quantities of carbon dioxide and ozone, also traces of ammonia and the rare gases helium, neon, krypton, and xenon, as well as minute quantities of the gases which escape from factories, natural-gas wells, coal mines, cooking rooms, and similar sources. Water vapor is always found in the air, as are also solid substances, which in the form of fine dust have been found at the highest altitudes yet attained by men.

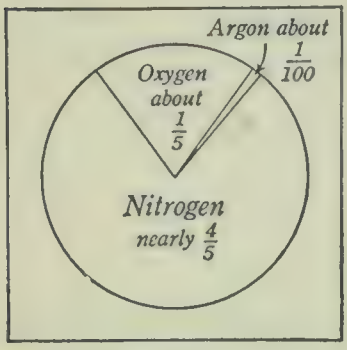


FIG. 14. Can you name other substances found in the air that are not named in this diagram?

*It must be understood that the different parts of the air are not combined with one another, but are merely mixed together. Dust may be present sometimes only in a trace and sometimes in such large quantities as to form a dark cloud. Thus the amounts of dust (and also of water vapor) in the air vary much more widely than do the proportions of the principal gases composing the air.

***Characteristics of oxygen.** In many respects oxygen is the part of the air which concerns us most. Unlike the other gases of the air, oxygen is a very active substance. That is, it is the only one of the atmospheric gases which combines readily with other substances to form new substances.

Although when we breathe we take in all of the substances composing the air, we make direct use of oxygen only. Nitrogen and the other gases usually in the air are not known either to be directly harmful[1] to us or to be of use to us. The dust may be harmful, as will be shown later, or sometimes such a harmful gas as carbon monoxide may become mixed with the air.

Since oxygen cannot be seen or taken in the hands, we must learn about it by other means. Oxygen can be taken from the air for examination, but it is more easily secured in other ways. Substances which contain oxygen may be broken up in such a way that the oxygen is set free and may be caught in glass tubes or other vessels and then examined (Fig. 15). A common substance for this use is potassium chlorate, a white substance which is sometimes used as a medicine for sore throat.

[1] *Harmful* (harm'ful): causing harm or injury.

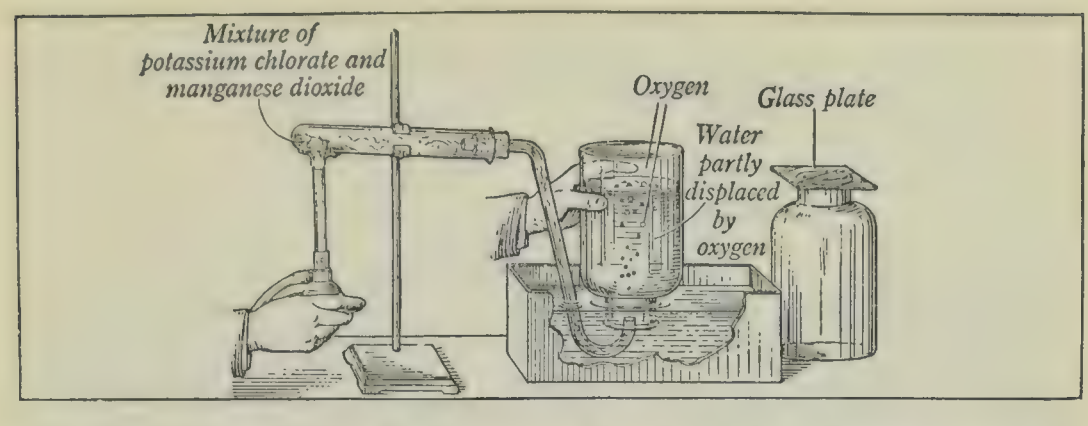


FIG. 15. Preparing oxygen. First mix the chemicals loosely (without grinding) in a clean, dry dish. Do not collect the first gas which escapes from the tube. Why?

Experiment 4. How may oxygen be prepared from potassium chlorate? Place a mixture of three parts of potassium chlorate and one part of dried manganese dioxide in a test tube. Arrange tubes and bottle as in Fig. 15. (A glass tube from within the test tube extends through a tightly fitting rubber stopper, then beneath the surface of the water in a dish. The free end of the tube under the water is placed in the open end of an inverted water-filled bottle.) Heat the mixture in the test tube by passing the flame back and forth over the test tube. Both the potassium chlorate and the manganese dioxide contain oxygen, but only the potassium chlorate gives up its oxygen. The manganese dioxide, merely by being present, causes the potassium chlorate to give up its oxygen much more rapidly than it would if heated alone. As the mixture is heated slowly, bubbles of oxygen pass through the glass tube into the bottle, and crowd out the water in the bottle. Collect two or three bottles of oxygen for study. To keep the oxygen in the bottle place a smooth glass plate tightly over the mouth of the bottle while it is still under the surface of the water. The bottle may then be placed upright upon the table.

*Oxygen when first prepared by this method has both color and odor, because it is not entirely pure. Pure oxygen has no color, taste, or odor. Oxygen is not a combustible[1] substance (that is, oxygen does not burn), but it is a supporter of combustion (that is, many other substances burn readily in oxygen). Thus if a piece of wood is lighted, the flame then blown out, and the wood thrust into the oxygen before the burning coal on the wood has

[1] *Combustible* (kom bus'ti bl): able to burn. *Combustion* (kom bus'chun): the act of burning or of oxidizing (see Glossary).

FIG. 16. An example of rapid oxidation. Can you explain why a bullet leaves a gun when the gun is fired?

gone out, the wood will at once burst into flame. Likewise if the end of a piece of iron picture wire is heated very hot and while still incandescent[1] is thrust into a jar or bottle of oxygen, it will burn vigorously, giving off dazzling sparks. Thus the wood and the iron oxidize[2]; that is, they combine with oxygen and form substances that are called oxides. The process by which oxygen combines with some other substance to form a new substance is known as oxidation. Thus the burning of iron or wood is an example of oxidation. The iron and the wood oxidize, and oxides are formed, as will be explained later.

Rapid oxidation and slow oxidation. Gunpowder and dynamite contain chemicals (see Glossary) which oxidize readily. The oxygen used for this oxidation is a part of the gunpowder and the dynamite. It is stored in them in much the same way that oxygen is stored in potassium chlorate (Experiment 4, p. 29). When the gunpowder or dynamite is "set off," the oxidation takes place very rapidly. Gases are produced. These gases require hundreds of times the space that was occupied by the powder which was oxidized. Consequently the gases expand violently, causing an explosion. Such oxidation may be put to good use in blasting

[1] *Incandescent* (in kan des'ent): white-hot, or glowing with heat.
[2] *Oxidize* (ox'i dize): to combine with oxygen.

masses of rock or the stumps of trees (Fig. 16). It may also be the means of violent and harmful destruction. Burning and explosions are examples of rapid oxidation. Examples of the frightful destruction which rapid oxidation may cause are all too common. It is likely, however, that you are not familiar with many examples of slow oxidation, although these also are very common. The rusting of iron is a good example.[1]

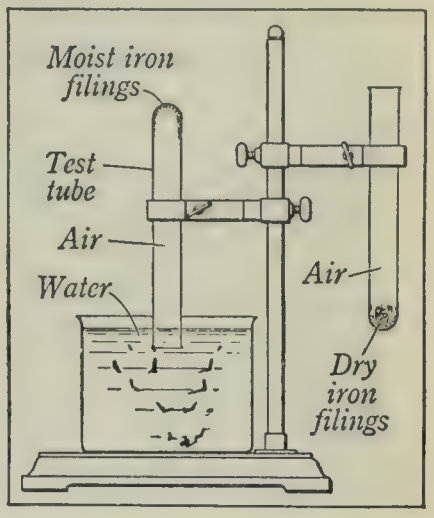


FIG. 17. **Exercise on Scientific Method (Isolating the Experimental Factor)**: Moisture is the experimental factor[2] in this experiment. Explain

Experiment 5. Will iron oxidize more readily in relatively dry air or very moist air? Measure two equal small quantities of fine iron filings. Moisten one portion and leave the other dry. Spread the moist filings over the bottom and sides of a test tube, the walls of which are wet. Invert this test tube in a beaker of water (Fig. 17). Put the second portion of filings into a dry test tube and place it beside the first. Mark on the outside of the test tube the water level inside the test tube which contains the moist iron filings. From day to day examine the filings in each test tube. Describe any differences you observe. Answer with a complete sentence the question asked at the beginning of this experiment. Has the water level changed in the test tube which contained the moistened filings? If so, mark the new level and measure the fraction of the test tube which is now filled with water. How do you account for each of your observations in this experiment?

Exercise on scientific method (using controls). The test tube containing the dry filings serves in this experiment as the control. Why is it necessary?

All about us are decaying materials that are slowly oxidizing. Iron and steel objects, for example, are oxidizing, when there is moisture as well as oxygen present, to form rust. The processes

[1] TO THE TEACHER. To avoid confusing the pupils it seems wise here to treat rust as a simple oxide of iron, and the other factors may be dealt with if later work is done in chemistry.

[2] Every factor in the control is exactly like that in the experiment except one. This one factor, which is different, is called the *experimental factor.*

FIG. 18. Painting an automobile body. The paint is sprayed on the metal surface by compressed air. How does the paint protect the metal?

occur so slowly that they are usually not noticed. We can hear and see the explosion which tears down a building, but we cannot hear and are not so likely to see the gradual oxidations of many kinds of property which are no less certainly being oxidized.

***Oxygen and energy.** Oxygen is necessary in the life processes of practically every living thing. The ways of securing oxygen vary in different animals and plants, but in all of them oxygen combines with food and other substances in every living part of the organism.[1] This oxidation of food gives the organism its energy. By means of this energy the organism does its work, whatever it may be — whether growth, heartbeat, running, or thinking.

Paint protects surfaces from oxidation. Many people think that the main reason for using paint is to make fences, houses, and the like look more attractive. Paint does make a building more beautiful, but that is not the chief reason for using it. Its chief purpose is to protect the surface of the building from oxygen and moisture in the air (Fig. 18). Paint consists of a colored powder, called a pigment, mixed with oil, usually linseed oil. We hear the expression "paint dries." This "drying" is not really

[1] *Organism* (or'gan izm): an animal or a plant (see Glossary).

drying in the same sense that water dries, that is, by evaporation.[1] When paint dries, the oil oxidizes. This oxidized oil makes a tough film, which is a thin skin covering the surface. This film holds the pigment to the surface. The pigment furnishes color, provides body for the oil film, and makes the oxidation of the oil take place more rapidly. "Driers" are substances which help to make the oil oxidize faster. They do this in the same way that manganese dioxide helped to make the oxygen come from the potassium chlorate faster in the oxygen experiment (see page 29).

*__Carbon dioxide one product of oxidation.__ You are familiar with carbon dioxide as the gas which bubbles from soda water. Carbon dioxide is ordinarily found in air in small quantities (about 1 part in 3000 of air by volume). It is slightly heavier, volume for volume, than the rest of the air. Consequently it tends to settle close to the earth's surface and is sometimes found in considerable quantities in wells and close to the floors of caves. It is constantly being released into the air by the oxidation or combustion of fuel, by the breathing of living things, and by the decay of all sorts of substances. It is estimated that during each hour about two and one half tons of carbon dioxide are breathed into the air by each million human beings. When we consider the innumerable[2] other living things which breathe out carbon dioxide, and that these would soon die if they could not get rid of it, it is evident that its production is continual and large.

Experiment 6. How may carbon dioxide be prepared? Will it burn? Will wood burn in it? Does it have any effect on limewater? Put a tablespoonful of baking soda into a drinking glass. Pour a little vinegar or lemon juice on the soda. The bubbles which immediately form are carbon dioxide gas, which remains in the bottom of the glass. When the bubbling stops, thrust a burning match into the top of the glass. Does carbon dioxide burn? Does the wood burn in it? Dip a glass rod in clear limewater, then hold it in the carbon dioxide in the glass. What change occurs in the limewater?

Although carbon dioxide results from the oxidation of materials within the bodies of plants and animals, yet if this carbon dioxide

[1] *Evaporate* (e vap'o rate): to change a liquid or a solid into a vapor by heating. *Evaporation* (e vap o ra'shun): making a substance into a vapor.

[2] *Innumerable* (in nu'mer a bl): too many to be counted.

becomes present in too large quantities it is harmful to the organisms that produce it. It is not, however, a poison, as has sometimes been stated. The excessive amount seems harmful chiefly in ways not fully known. If present in greatly excessive amounts carbon dioxide may cause death, though there is probably never enough present even in cities or in crowded rooms to cause injury. All green plants consume carbon dioxide in their processes of making food, and return oxygen to the air. Thus they are very important in maintaining the oxygen supply (Chapter XXX).

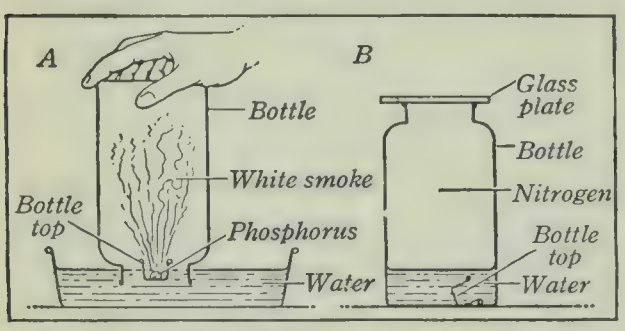


FIG. 19. **Self-test on Scientific Facts:** If you were presented with four exactly similar jars filled, respectively, with nitrogen, oxygen, carbon dioxide, and air, how might you determine which jar contained each of these gases?

Nitrogen. If we remove the oxygen from air, what remains is chiefly nitrogen. While other substances are present in small quantities, the nitrogen will be sufficiently pure for study. Let us secure a sample of nitrogen and see what it is like.

Experiment 7. What are some characteristics of nitrogen? Place in a bottle cover as much red phosphorus as would equal the size of a pea. Float the bottle cover containing the phosphorus in a dish of water (Fig. 19, *A*). Heat red-hot one end of an iron nail or a file. Then with the hot end light the phosphorus. *Immediately* cover the bottle top with a jar. [CAUTION: *Be sure not to inhale the fumes of the burning phosphorus.*] The heat energy causes the phosphorus to combine with the oxygen of the air, and a dense white solid substance like smoke is formed. This slowly settles and dissolves in the water. What happens with respect to the level of the water in the jar as the powder dissolves in the water? When all the powder has dissolved, hold a glass plate under water and tightly over the mouth of the jar, and then remove the jar from the dish of water. Place the jar right side up (Fig. 19, *B*). Keep the glass plate over the mouth of the jar, so that you may study the nitrogen. Measure the height of the water in the jar and the height of the jar. About what fraction of the air which filled the jar at the beginning of the experiment was oxygen?

About what fraction of the air which filled the jar was nitrogen? Note the color of the nitrogen. Thrust a lighted splint into it. Does the wood continue to burn in the nitrogen? In a statement summarize the facts about nitrogen you have learned from this experiment.

***Properties of nitrogen.** Nitrogen is known as an inert or inactive[1] gas, because it does not readily combine with other substances as oxygen does. When animals and plants breathe, nitrogen enters them, but it passes out again without being changed. Yet it makes life possible, because the percentages of both oxygen and carbon dioxide in the air would be too great for use by living organisms if it were not for the presence of nitrogen. Thus nitrogen may be said to dilute[2] the oxygen and carbon dioxide of the air. Nitrogen is also supremely important as a necessary part of many food substances that are required by both plants and animals.

Rare gases in the air. The rare gases in the air include argon, helium, neon, krypton, and xenon. Like nitrogen, all these are inert gases. Until recently they were regarded merely as interesting substances or as scientific curiosities, but important commercial uses have now been found for three of them. Helium is used in dirigible balloons. Nearly all of the world's supply of this valuable gas is controlled in the United States. Argon is used in the globes of incandescent lamps. Neon finds wide use in electric signs. It is thought that still further uses will be made of these gases.

***Water vapor in the air.** The air over deserts contains but little water vapor; that over and near oceans, lakes, and rivers contains much. When the amount is more than the air can hold, this vapor forms clouds, and it may fall as rain, snow, sleet, or hail.

Almost all objects upon the earth's surface contain some water. All living things require water. Water in the form of an invisible vapor is constantly being added to the air from innumerable

[1] *In, un, non, dis,* and sometimes *im,* at the beginning of a word give the word the opposite meaning. Thus *inactive* means "not active."

[2] *Dilute* (di lute'): to make a substance weaker or thinner by adding another substance to it; thus, strong coffee is diluted, or made weaker, when water is added to it.

FIG. 20. The water given off during the growing season by 100 acres of corn yielding 50 bushels to the acre would, if frozen, make a layer of ice 1 inch thick over the surface of a lake about 1 mile square. Why cannot corn be grown in desert regions?

sources by evaporation. The amount of water carried into the air by any single acre of growing plants during a season is enormous. For example, an average of 15 tons of water is carried into the air during the production of one bushel of ripened corn. A corn crop of 50 bushels to the acre would then have carried into the air an average of 750 tons of water per acre during the entire growing period of the corn (Fig. 20).

Dust in the air. Various kinds of materials, such as rocks, automobile tires, street and highway surfaces, soil, and clothing, are constantly being reduced to dust. Some of this dust is fine enough to be carried by the air even when only slight air movements occur. Some of it can be carried only when strong winds are blowing. Volcanic[1] dust (Fig. 21) is sometimes so fine that it has been known to remain in the air for many months or even years, and even to circulate several times round the earth before falling.

Part of the dust consists of small living things that have become very dry. Some of this living dust has been found as high as two miles above the earth. It has been found high above the oceans

[1] *Volcanic* (vol kan'ik): from a volcano (see Fig. 21).

Publisher's Photo

FIG. 21. Mt. Vesuvius in action. What besides volcanic dust should you expect such a volcano to be adding to the atmosphere?

as well as above the land. When living dust alights in favorable places, it proceeds to grow, as will be explained in Chapter XXX. Thus the air may be said to carry both living and dead dust.

Self-test on Problem II–B. (*Do not write in the book.*) **1.** Name the substances which compose the air in order, beginning with the most abundant.

2. There is nearly four times as much *argon* as there is *oxygen* in the air.

3. The most active substance in the air is *carbon dioxide.*

4. If a piece of the metal magnesium in the form of a ribbon is heated and is then thrust into oxygen, it will burn rapidly with a brilliant light. This proves that the *oxygen* is combustible. Also this is an example of *slow oxidation.*

5. The chief reason for painting a building is to protect it from *insects* and *nitrogen.*

6. The breathing of animals and combustion add to the air great quantities of (1) nitrogen; (2) oxygen; (3) carbon dioxide; (4) dust; (5) argon; (6) neon.

7. It would be *difficult* to start a fire in pure nitrogen.

8. The only substance in the atmosphere which is partly composed of living things is the ~~*water vapor.*~~ DUST

Self-test on Scientific Principles. How would you explain and illustrate this principle to a boy or a girl of your own age who had never studied science: "The air pressure decreases as the altitude increases"?

You would need first to state this principle again in simpler language, using other words in place of *decreases*, *altitude*, and *increases*. Can you do this?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why have men been unable to measure the exact height of the atmosphere?

2. Would the atmospheric pressure be greatest on a mountain top, in a mine, or at the sea level? Explain.

3. Why do balloons which are sent up as high as possible with recording instruments burst in the upper altitudes?

4. Sometimes oily rags take fire by themselves. Can you explain such spontaneous combustion?

5. What would be likely to happen if the air were suddenly to change in its proportions of oxygen and nitrogen so as to be made up of about four parts of oxygen to one of nitrogen?

6. How many harmful uses of rapid oxidation can you name?

Exercise on Scientific Method (Inventing Experiments). Can you plan an experiment to prove that there is dust in ordinary air? Make a diagram to show how you would perform the experiment.

Exercises on Scientific Attitudes. 1. Joseph Priestley (1733–1804) was a British scientist whose last years were spent in Pennsylvania. It had been believed by scientists that all combustible substances contained something called *phlogiston* which escaped as the substance burned. Thus coal was thought to be almost pure phlogiston. While heating red oxide of mercury one day, Priestley noticed that a gas was given off. Not knowing what this gas might be, he at once collected it for study. When he put a lighted candle into the gas, the candle burned brilliantly. He called the gas (which was oxygen) "dephlogisticated air," because he thought it was a substance which contained no phlogiston but which therefore absorbed phlogiston from a burning substance as a sponge absorbs water. Priestley soon concluded that air is a mixture of his newly discovered "dephlogisticated air" and "phlogisticated air" (later known as nitrogen). He later discovered and experimented with a number of other gases. He was surrounded with evidence that the phlogiston theory was false, yet he obstinately continued to believe the theory as long as he lived.

Which scientific attitudes (pp. 12 and 13) did Priestley possess and which did he not possess?

2. Antoine Lavoisier, a French scientist (1743–1794), made few new chemical discoveries, but he studied and explained the discoveries of the earlier chemists. He first proved by careful experiments the falseness of the idea, previously held, that water could be changed into earth. Learning of Priestley's discovery of "dephlogisticated air," he repeated Priestley's experiments. Soon he hit on the true explanation of combustion and the nature of oxygen, but before announcing his conclusions he proved their truth by many experiments. His results dealt the death blow to the phlogiston theory. He named oxygen, hydrogen, and nitrogen and was the first to believe that the human body is a chemical laboratory. He thought that oxygen starts the body heat which keeps life going. Lavoisier was executed during the French Revolution.

What scientific attitudes do these facts about Lavoisier indicate that he possessed?

3. How do these accounts of the work of Priestley and Lavoisier illustrate attitude No. 4, p. 12?

4. A letter correctly addressed to the home of Mr. John Smith of Portland, Maine, is sent by error to Portland, Oregon, before finally arriving at Mr. Smith's address. But meanwhile Mr. Smith has started on a trip. The letter is forwarded to Montreal, then to Toledo, and finally to Seattle, where it is delivered to him. Where does Mr. Smith live?

Which of the scientific attitudes relates to this problem?

5. During a football game one team has a chance to score by either kicking a field goal or making a touchdown. Which should it do?

Which of the scientific attitudes relates to this problem?

Special Reports. 1. Make a list of the most important events in the history of the stratosphere flights by balloon and by airplane. (Consult aircraft yearbooks and scientific journals, or a file of World Almanacs.)

2. Discuss the possible dangers from chemicals in paint and varnish. (Consult textbooks in chemistry.)

3. Describe the experiments on air pressure conducted by Torricelli and Galileo. (Consult an encyclopedia.)

4. Describe the water barometer of Otto von Guericke. (Consult a history of science or an encyclopedia.)

Book for Reference

Meister, Morris. Water and Air. Charles Scribner's Sons, New York.

Chapter III · Using the Energy of the Air in Doing Work

Questions this Chapter Answers

What were some early experiments with air pumps?
What is suction?
How is the energy of the atmospheric pressure used in the operation of the vacuum sweeper, the lift pump, and the siphon?
How is the energy of compressed air used in the operation of various machines, in working under water, and in transportation?
How is the energy of the atmospheric pressure and of compressed air used in the operation of the force pump?

Problem III–A · How can the Energy of the Atmosphere be Used in Doing Work?

The Magdeburg[1] hemispheres. Primitive water pumps of one sort or another were used before the time of Christ. But until the middle of the seventeenth century it was not known that air as well as water could be pumped. At this time Otto von Guericke,[2] Mayor of Magdeburg, Germany, during his leisure experimented with air pressure and invented the first air pump, or "suction pump." With this pump he demonstrated the force of the atmospheric pressure before the emperor and his "diet," or legislature. Guericke first made a hollow copper ball, or globe, two feet in diameter, the two halves of which fitted together very closely. These halves were not bolted or joined together in any way. To this globe he fitted a tube so constructed that it could be opened or closed. He attached his air pump to this tube. The tube was opened and the air pumped from the globe. The tube was then closed so that air could not enter the globe. Horses were then hitched to each hemisphere (Fig. 22), but sixteen horses were required to pull the two halves of the globe apart.

[1] *Magdeburg* (mog'de boorg) : a city in Germany.
[2] *Guericke* (ger'ik a) : a German scientist (1602–1686).

FIG. 22. The demonstration with the Magdeburg hemispheres as pictured on the cover of the book describing Otto von Guericke's experiments. What would probably have happened if air had suddenly been allowed to enter the globe? Explain

This demonstration with the Magdeburg hemispheres was viewed with wonder and astonishment by the emperor and his lawmakers. They did not fully understand what held the halves of the globe together. They thought that suction held the halves together, but even today the correct meaning of the word *suction* is not generally understood.

***Suction a push and not a pull.** Many people believe that suction means that something is being pulled into a space. This idea, that suction is drawing or pulling, is not correct. Whenever there is suction, a partial vacuum is always formed into which air or anything else may be forced by the pressure of the atmosphere. This is because the energy of the outside air is greater than the energy of the partial vacuum. It is never possible to produce a perfect vacuum, because it is never possible to remove absolutely all the air from any space. The more nearly perfect the vacuum that is produced, the stronger is the outside push in the direction of the vacuum. This is because of the increasing difference between the diminishing air pressure within the partial vacuum and the undiminished atmospheric pressure outside the partial vacuum. A perfect vacuum, if such were possible, would contain nothing whatever and would have no energy. It would there-

fore be absurd to think that a perfect vacuum could do anything. The air pressure outside the vacuum, however, can push into a space in which there is a smaller opposing pressure.

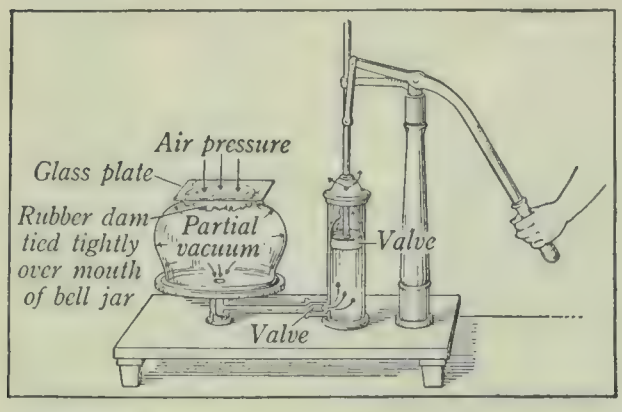


FIG. 23. Suction is a push and not a pull. Sometimes one hears the unscientific term "vacuum pressure." Can you explain why this is an incorrect term?

In Guericke's demonstration there were almost fifteen pounds of atmospheric pressure on every square inch of the outside surfaces of the Magdeburg hemispheres. As the air inside was pumped out, the difference between the pressure on each square inch of surface outside and inside the hemispheres increased. Therefore there was finally a difference of several tons between the total pressure of the air outside holding the hemispheres together and the pressure of the partial vacuum inside.

Can you prove that suction is a push? You can easily prove with an air pump and bell jar or palm glass (Fig. 23) that suction is a push and not a pull. Tie a sheet of rubber dam, such as dentists use, so that it fits tightly over the smaller open end of the bell jar. Cover the surface of a glass plate with plenty of vaseline; then press the plate firmly over the rubber so that no air can get under the edge of the plate. The plate holds the air outside the bell jar away from the rubber, while the rubber is not protected in any way from conditions inside the jar. Then pump the air from the jar by use of the air pump. A partial vacuum is now formed in the jar, but this partial vacuum does not pull the rubber down into the jar. The rubber remains as it was. Now slide the glass plate off the rubber. As soon as the outside air pressure, which had been supported by the plate, strikes the rubber, it pushes the rubber down into the partial vacuum in the jar. This proves that suction is a push and not a pull.

Another experiment will help to prove that suction is a push and not a pull.

Experiment 8. Does air exert pressure upon the surfaces of objects? Attach the tube of a vacuum pump to an empty sirup or varnish or gasoline can, by means of a one-hole rubber stopper and short glass tube, as shown in Fig. 24. Pump the air out of the can and observe the results. The arrows drawn with their points pressing against the outside and inside surfaces of the can represent the air pressure before any air has been removed from the can. How would you need to change these arrows to represent the air pressure inside and outside the can after most of the air has been exhausted from the can? Answer the question at the beginning of this experiment and justify your answer.

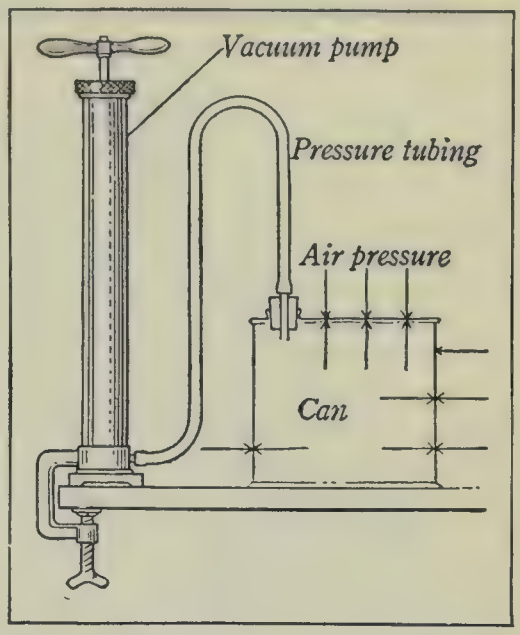


FIG. 24. What will be the total force exerted on the top of the can if the surface of the top is 30 square inches?

***Air pressure and the vacuum sweeper.** When anything occurs which takes the air away from a place, the air round about, because of its greater pressure, flows in and takes the place of the air that was removed. Thus when the bulb of a medicine dropper is pressed the air within is removed. When the pressure is released, a partial vacuum is produced in the bulb. Hence air or water is forced into the bulb again by the greater pressure of the atmosphere outside.

*The energy of air pressure is used with the vacuum sweeper. A fan (Fig. 25) is attached to an electric motor. As the fan is whirled by the motor, its blades push air out of the cleaning tube of the sweeper and into the dust bag. A partial vacuum is thus formed within the tube. Since the air pressure outside the sweeper is now greater than that within the tube, air is forced from the room into the sweeper, carrying with it any substances which are light enough to be carried by the air current. The air pressure within the dust bag is greater than that outside. Hence air is forced through the walls of the dust bag, which are of cloth finely enough woven to hold the dust while allowing some of the air to escape.

***Lifting water with atmospheric pressure.** Many homes secure their water supply by means of what is commonly called a lift pump. A pipe or pump stock extends into the water supply in the well (Fig. 26). The main body of the pump fits tightly into the upper end of the long stock. There are two valves in the pump. One (valve *a*) is on the piston, the other (valve *b*) is at the bottom of the pump. Ordinarily valve *a* is a leather ring or washer which extends around the edge of the piston and fits the barrel of the pump snugly when the piston is raised. The valves open and close alternately. All the connections must be airtight. Why?

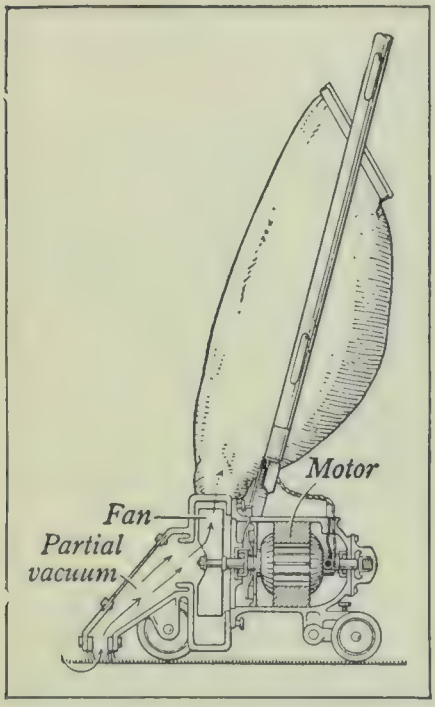


FIG. 25. Would a vacuum sweeper be more effective or less effective on a mountain top than in a valley? Explain

*During the first strokes of the piston the lift pump operates like a vacuum pump. As the handle is raised, the piston is lowered. The air that is between valves *a* and *b* holds valve *b* shut and forces valve *a* open. Some of the imprisoned air now escapes. When the pump handle is lowered, the piston is raised. A partial vacuum is immediately formed between the two valves. Consequently valve *a* is forced shut by the greater pressure of the atmosphere above it and valve *b* is forced open by the greater pressure of the atmosphere below it. As some of the air in the pump stock escapes through valve *b* the space below valve *b* becomes a partial vacuum. The greater pressure of the atmosphere on the surface of the water in the well forces water up a little distance into the pump stock. During the next downward and upward strokes of the piston more of the air is removed from the pump stock in the same way. The atmospheric pressure in the well forces water higher up the pump stock as the air is exhausted from it. After a sufficient number of strokes water enters through valve *b* during an upward movement of the piston. During the next

downward stroke of the piston the water is forced through valve *a*. On the following upward stroke water is raised to the

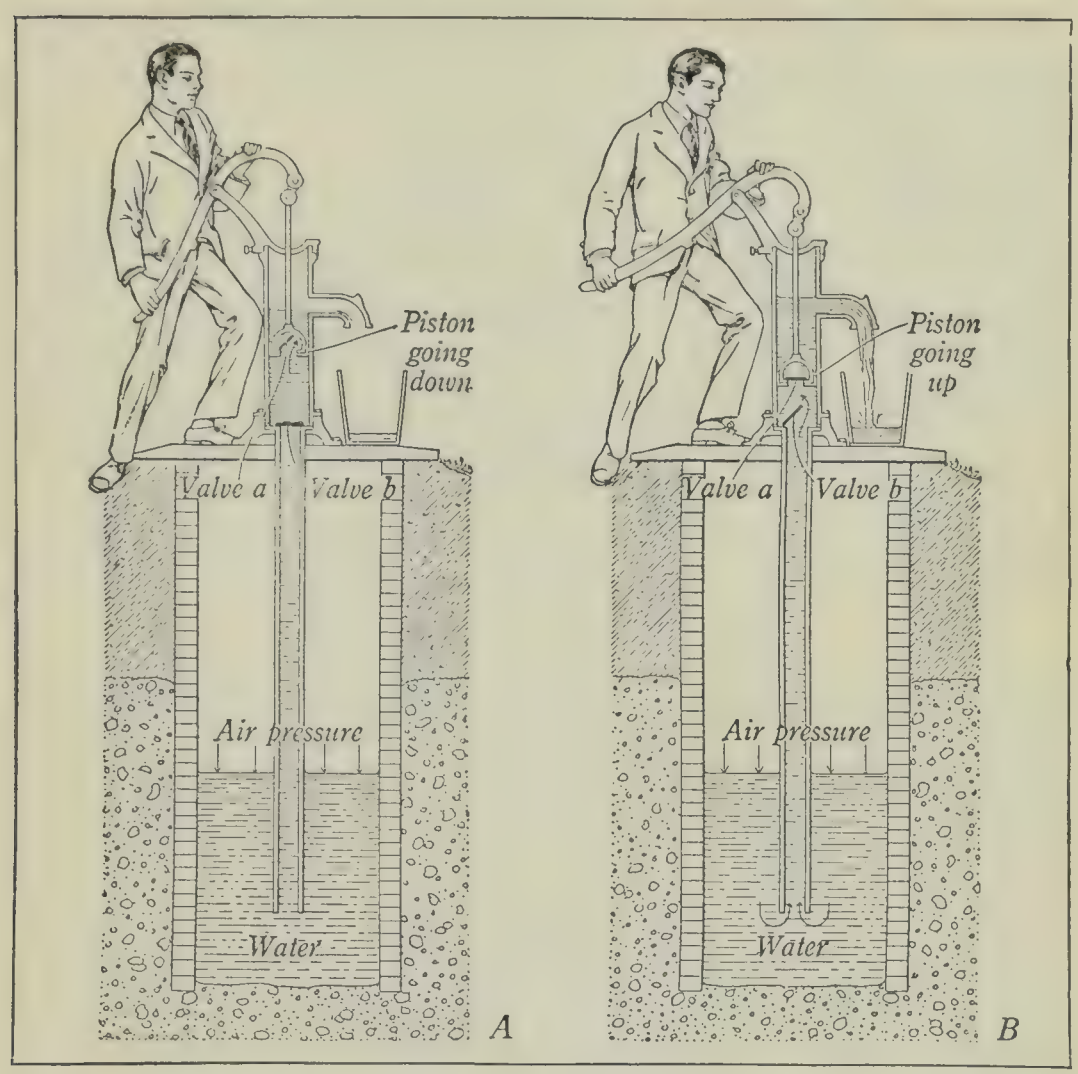


FIG. 26. Lift pump. A lift pump could raise water from a deeper well near the ocean than in a mountain valley. Explain

spout and pours out. As the pumping is continued the pump stock and pump are kept filled by the pressure of the atmosphere in the well.

A lift pump will rarely lift water more than twenty-five to twenty-eight feet, (1) because there is friction of water in the pipe and (2) because the valves cannot be made completely tight.

***The siphon is operated by air pressure.** If a tube is entirely filled with water and is placed with the ends in two vessels containing water (Fig. 27), the water will flow through the tube if

the water level in one vessel is above the water level in the other vessel. It will flow always from the higher level to the lower level. Any tube when used in this way is called a siphon. There are many practical uses of the siphon, as will be seen later.

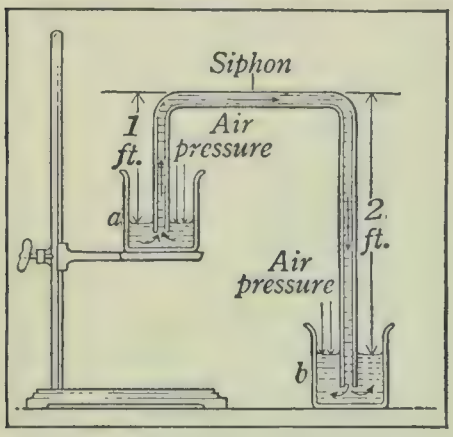


FIG. 27. Would water flow more or less rapidly through the siphon if the difference between the water levels in the two vessels were increased? Explain

We learned in Chapter II that at sea level the air pressure is great enough to hold up a column of mercury about 30 inches high or a column of water about 34 feet high. If no air is allowed to enter the siphon tube, the air pressure at sea level would be able to hold up a column of water about 34 feet high in each side of the siphon, from the water surface to the bend. In Fig. 27 the air pressure on the surface of the liquids in both vessels is the same, but the air pressure is holding up a longer column in vessel *b* than in vessel *a*. Thus less of the air pressure on the surface of the water in *a* is being used to hold up the column of water than is the case with the air pressure on the surface of water in *b*. That is, if the column above *a* is 1 foot high, the air pressure on the surface of *a* could hold up a column about 33 feet higher than the one it is supporting. Similarly, if column *b* is 2 feet high, the air pressure on the surface of the water in *b* could hold up a column of water about 32 feet higher than the one it is supporting. The remaining, or unused, air pressure is therefore greater on the surface of *a* than it is on the surface of *b*. Hence the remaining air pressure on *a* forces the water over into *b* in spite of the fact that the remaining air pressure on *b* tends to push the water back into *a*. In actual practice the air pressure cannot lift water higher in a siphon than in a lift pump (that is, not more than from 25 to 28 feet) because of the friction of water in the tube.

Self-test on Problem III–A. (*Do not write in the book.*) 1. A space from which part of the air has been removed is called a partial __(?)__.

2. When you drink lemonade through a straw, you first make a partial vacuum in your mouth. The lemonade is then *pulled* into your mouth

because the pressure of the air in your mouth is *less* than the pressure of the air upon the lemonade in the glass.

3. When a vacuum cleaner is being used, the pressure *within* the tube is *greater* than 15 pounds per square inch.

4. A lift pump on a *hill* would lift water higher than would one in a *valley*.

5. Whenever there is suction, objects may be *pulled* into the partial vacuum, but are never *pushed* into it.

6. A siphon in a vacuum would work (1) not at all; (2) to some extent; (3) as well as it would with ordinary air pressure; (4) slightly better than with ordinary air pressure; (5) much better than with ordinary pressure.

7. In a deep mine the air pressure would probably force water *less* than twenty-eight feet in a siphon tube.

Problem III–B · How can the Energy of Compressed Air be Used in Doing Work?

***Compressed air possesses energy.** Compressed air is the opposite of a partial vacuum, since instead of removing air from a closed space we pump more air into it. The pressure in any space containing compressed air is greater than the pressure of the surrounding atmosphere.

There are many common examples of the use of the energy of compressed air. Of these perhaps the most familiar is its use in automobile and bicycle tires. The earliest rubber tires for bicycles and carriages, and even some of the first tires for automobiles, were of solid rubber. It was a long time before hollow rubber tires could be made to hold air with enough compression[1] to support the vehicle.[2] It is much more comfortable to ride on compressed air than on solid rubber. If, however, the inflated[3] rubber tire becomes worn thin or strikes a sharp object, it may become unable to confine the air and a "blowout" may result.

Compressed-air machines. There are many other common examples of the use of the energy of compressed air. Air drills are

[1] *Compression* (kom presh'un): act of compressing or state of being compressed.

[2] *Vehicle* (ve'i kl): a carriage or similar means of transportation.

[3] *Inflate* (in flate'): to cause to expand by forcing in a gas, as air.

Keystone View

FIG. 28. Riveting the frame of a skyscraper. **Special Report:** How are the rivets driven?

widely used in mining and in various types of construction work. Compressed-air drills and hammers are used for breaking concrete sidewalks and pavement when it is necessary to remove them. The iron rivets which hold together the bodies of steel vessels and the steel frames of buildings are driven and fastened with compressed-air machines (Fig. 28).

Compressed air, when released as an air jet, is used in such devices as the barber's hair-drying machine, the hand-drying machine, the automobile-tire filler, and the "paint gun" (Fig. 18, p. 32). The sand blast, which consists of an air jet which carries sand, is used in smoothing cast-iron surfaces and in cleaning the outside walls of stone or cement buildings. In the use of air brakes on street cars and railroad trains, compressed air forces the brakes against the wheels. The familiar shrill whistling sound that follows the use of air brakes is caused by the escape of the compressed air when the brakes are released. Door checks (Fig. 29), life belts, pillows, cushions, and many other devices may be listed among the articles in which compressed air may be used.

Air guns furnish a familiar example of the use of the energy of compressed air. Within the air gun is a piston without valves, which fits the gun barrel very closely. When the gun barrel is bent down, the air within it is compressed. When the gun is fired, the compressed air is released. It expands, driving with great force the shot, arrow, or bullet from the air gun.

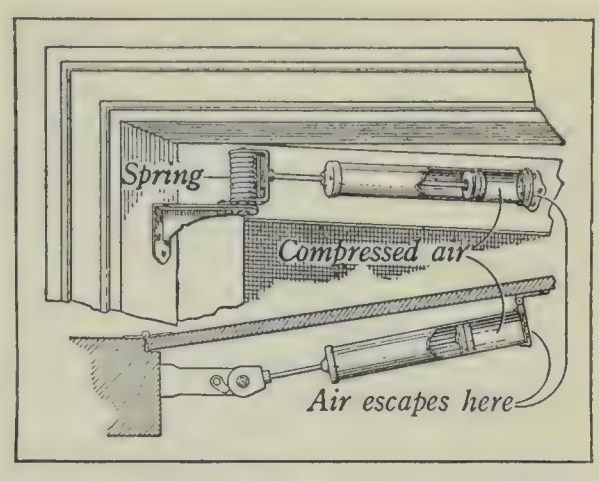


Fig. 29. Diagram of a door check, side view (above) and top view (below). The coiled spring pulls the door shut. As the door closes, the piston is pushed farther into the cylinder and compresses the air. The compressed air escapes through holes in the end of the cylinder, allowing the door to close softly. What would happen if the cylinder were airtight and no air could escape around the piston? Explain. Would a door check operate in a vacuum? Explain

Working in compressed air under water. When men must work under water, as in building foundations for bridges or dams or in building tunnels under rivers, compressed air is used to hold back the water while the work proceeds. Such work is carried on inside steel-walled cylinders called caissons (Fig. 30). As we learned in the study of the barometer, the pressure of water 34 feet deep is one atmosphere, or 15 pounds per square inch. Therefore the air pressure within the caisson must be increased to the extent of another atmosphere, that is, an additional 15 pounds per square inch, for every 34 feet of added depth under water. Men have worked in caissons more than 100 feet below the surface of the river, where the pressure was more than four atmospheres, that is, more than 60 pounds per square inch.

Men cannot work very long under such enormous pressures. Also they cannot withstand too sudden changes from air of one pressure to that of another. There is air in the human body — in the blood, in the lungs, in the ears, and, to some extent, in other parts of the body. When the air pressure on the outside of the body is greatly increased, air is forced into the blood and other body liquids. If later the air pressure is suddenly reduced, the air

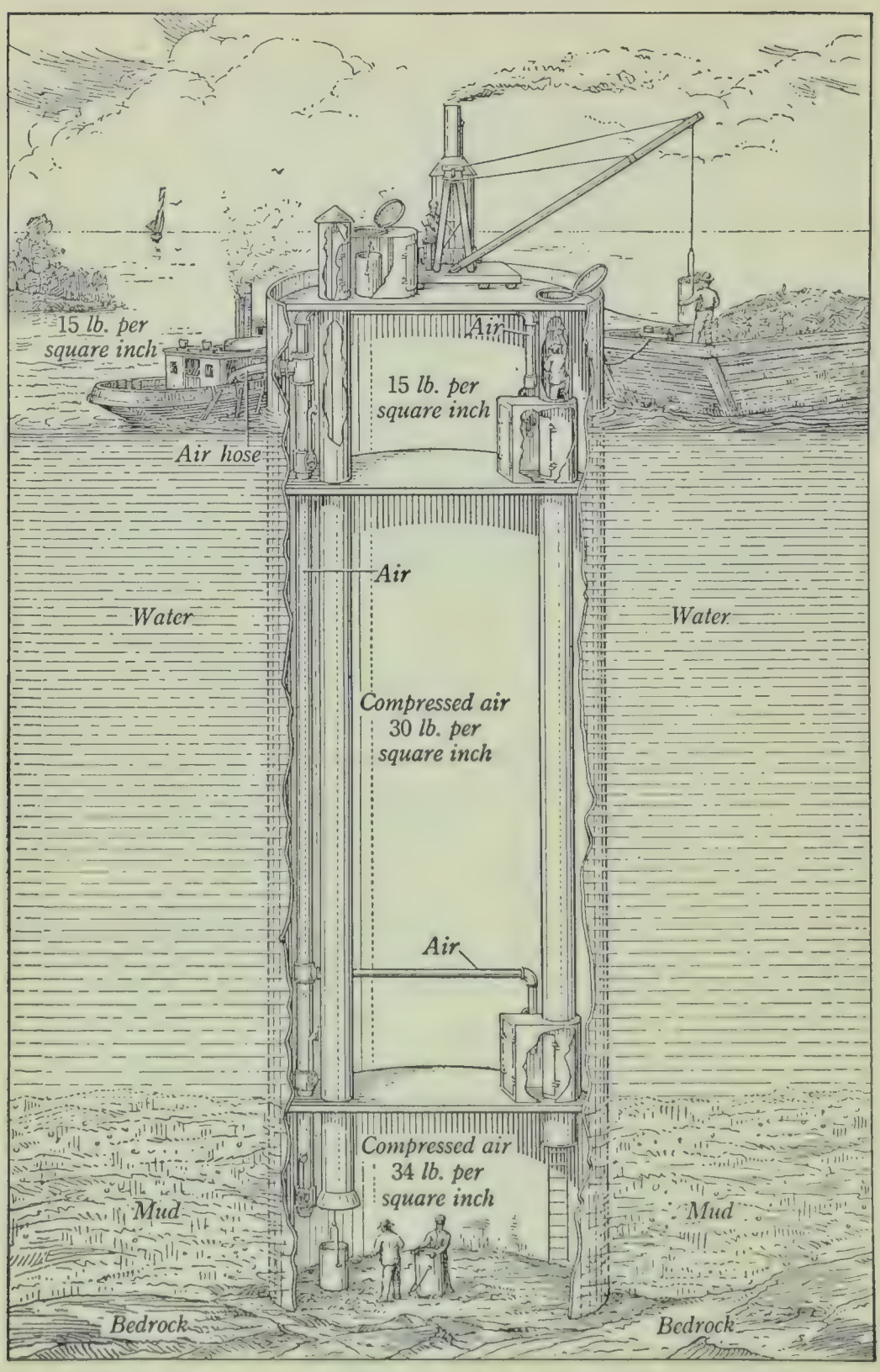


FIG. 30. Diagram of a caisson. Why is greater air pressure required within the caisson in deep water than in shallow water?

in the liquids forms bubbles which may cause serious illness. Also sudden changes in pressure may injure the eardrums. Therefore, when caissons are needed for work under water, use is made of several compartments,[1] each capable of being closed from the others. Different air pressures are maintained in the different compartments so that the workmen may become adjusted gradually to the different air pressures. In this way the air pressures may gradually become equal inside and outside the men's bodies, as they pass from one compartment to the next.

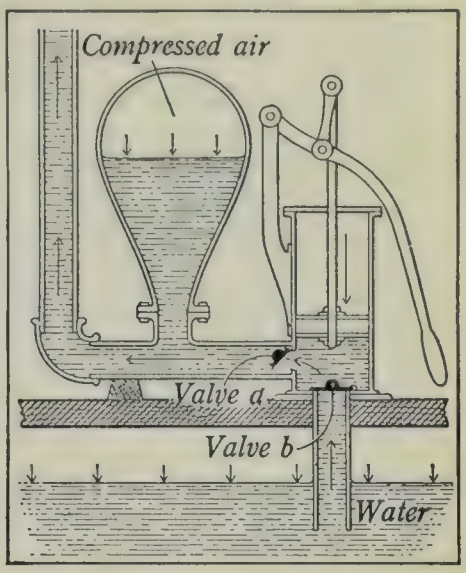


FIG. 31. Diagram of a force pump. Can water be raised to a greater height with a lift pump or with a force pump? Explain

***Lifting water with atmospheric pressure and compressed air.** The force pump differs from the lift pump in that it is constructed to throw water out of the pump, not merely to have it flow out. This is accomplished by arranging the valves as in Fig. 31. The piston attached to the pump fits tightly within the pump cylinder. Before water enters the pump the valves are forced open or shut by changing air pressures as the piston rises or descends, just as in the lift pump. In fact, the force pump itself operates like a lift pump. The outlet pipe, however, is equipped with an air chamber. As the piston descends, water is forced through valve *a* faster than it can escape from the pipe. Consequently some of the water is forced into the air dome, compressing the air in the dome. When the piston next rises and valve *a* is forced shut, the compressed air in the dome forces the water out of the spout. Thus the energy of the compressed air is used to maintain a steady flow while the pump is being filled. If the air chamber is large and the outlet or spout is relatively small, a sufficiently high degree of compression can be produced to force a jet or spray of water a long distance.

Transportation by air pressure. In stores it is common to see

[1] *Compartment* (kom part'ment): one of several divisions, as the different rooms of a building, or the drawers of a desk or of a filing cabinet.

the clerk put his sales slip and cash into a small cylinder, open a valve in the side of a tube, and put in the cylinder (Fig. 32). The valve snaps shut. Soon the cylinder, with its stamped slip and change, returns and drops into the clerk's basket. Let us see what causes this. Air is pumped into one end of the tube and out of the other end. The cylinder fits the tube tightly, so that there is compressed air on one end of it and a partial vacuum on the other. It is the greater air pressure against one end of the cylinder than against the other that pushes the cylinder to the central office, then in another tube pushes it back. In modern stores extensive systems of air tubes carry large sums of money and hundreds or thousands of messages and articles of merchandise. This work is done with a speed, safety, and accuracy not possible under the system of boy and girl messengers.

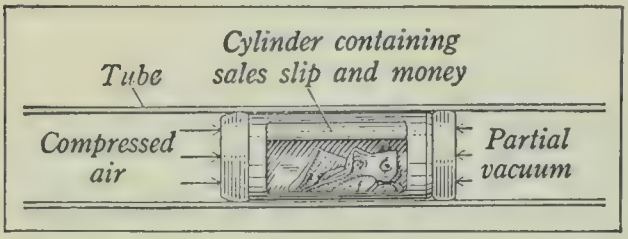


FIG. 32. Diagram of a cash-sales cylinder. Can you explain why the cylinder travels toward the right?

In large cities the Post-Office Department uses air tubes for transporting cylinders containing mail bags from one division to another within the city. In this way the mail not only is carried much more rapidly but is less likely to suffer accident or loss than when carried by vehicles.

Self-test on Scientific Principles. How does inflating an automobile tire illustrate this principle: "The greater the compression that is applied to a gas which cannot escape, the greater is its pressure"? Can you think of other illustrations of this principle?

How many illustrations of this principle can you give from your study of Chapter III: "The air possesses energy and tends to move objects whenever there is a difference between its pressures at two points"? Can you give an original example of this principle?

Self-test on Problem III–B. (*Do not write in the book.*) 1. Compressed air is the opposite of a __(?)__.

2. When you blow up a balloon, there is *compressed air* in the balloon.

3. Compressed air has *more* energy than ordinary air.

FIG. 33. Without pouring or dipping the water, how can the boiler be emptied?

4. Within a caisson a barometer would register *slightly less* than thirty inches.

5. The *lift pump* uses compressed air to make the flow of water steady.

6. In a caisson the compartment nearest the surface of the water has the *greatest* pressure.

7. A cash-sales cylinder would travel *faster* through the tube if compressed air were forced into one end of the tube and if no air were pumped from the other end.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What is the actual air pressure in an automobile tire which is inflated to a pressure of thirty pounds per square inch?

2. What advantages have balloon tires over the small earlier types of tires?

3. Do automobile tires become harder or softer as the automobile ascends a mountain? Explain.

4. Why does a toy balloon burst when you squeeze it?

5. If you try to lift your foot out of mud when wearing rubbers, you are likely to pull your rubber off. Explain.

6. Gymnasium shoes are often made with cuplike disks on the soles. How do these prevent one from slipping?

7. If a window is open, the window curtains will be swayed inward or outward when the door is suddenly opened. Explain.

8. Make a bar graph similar to Fig. 118, p. 179 (fuel values), showing the water depths which correspond to the air pressures given in Fig. 30, p. 50 (caisson).

9. Can you solve the problem in the legend of Fig. 33?

Self-test on Scientific Attitudes. Suppose, as you are going home from school tonight, you were to see a man rush out of a yard carrying a small child in his arms. The child is screaming loudly as the man jumps with her into an automobile and speeds down the street, turning at the first corner. What should you do? Justify your answer by quoting one of the scientific attitudes.

Special Reports. **1.** Find out as many as you can of the uses of compressed air in your community. Can you explain how these devices operate?

2. Diagram and explain the action of a fire-engine pump. (Consult a textbook of physics.)

3. Report on some use of compressed air described in one of the books listed below.

4. Report on vacuum cleaners for furnaces and hot-air heating pipes.

Question for Debate.[1] *Resolved*, That partial vacuums are more useful in our modern civilization than compressed air.

Books for Reference

Adams, J. H. Harper's Machinery Book for Boys. Harper & Brothers, New York.

Cochrane, C. H. Wonders of Modern Mechanism. J. B. Lippincott Company, Philadelphia.

Cressy, E. Discoveries and Inventions of the Twentieth Century. E. P. Dutton & Co., Inc., New York.

Masters, D. Wonders of Salvage. Dodd, Mead & Company, New York.

[1] Unlike an ordinary debate, a scientific "debate" is never for the purpose of having either side win. It is an attempt to present the known facts on both sides of the question. The audience is interested not in who is right but in what is true. It is not unusual for a speaker to present facts and arguments on both sides of the question.

UNIT II · *Water and Man's Uses of It*

PROBLEMS DISCUSSED IN THIS UNIT

The old pioneer trails which led westward across plains, mountains, and deserts never were direct "as the crow flies." They wound and twisted because they had to follow routes which could be traveled and which provided sufficient water for the travelers and their animals. These supplies were needed at relatively short distances apart. The end of a day's travel usually found the wagon train in camp at a river, a stream, or a water hole. Whenever the pioneers planned to go forward into unknown country, it was necessary to send scouts ahead to find water.

In the earlier days of ocean travel it was usually necessary to take on at the port of departure all the fresh water needed for the entire voyage. Sometimes before the voyage was over the water in the wooden casks and tanks became so foul as to be almost unfit to drink. Yet it made life possible. If the water supplies became entirely exhausted and more water could not soon be obtained, a terrible death might follow.

Though the water supply may now seem of less concern than formerly, it is quite as important today as in earlier times. Indeed, the development of great industrial plants, and of dense human populations, has increased the need of ready and large supplies of water. We use water for so many purposes that an understanding of the problems of securing and using water is necessary.

The problems discussed in this unit are:

What are the nature and the distribution of water?
What are some important properties of water?
How is the energy of running water used in doing work?
What are the sources of water supply?
How is the water supply distributed to our homes?
How is the water supply made safe for drinking?
How is water used in keeping clean?
How is water used in disposing of wastes?

Chapter IV · Water and its Work

Questions this Chapter Answers

Where is water found on the earth?
What is water?
What kinds of substances does water dissolve?
Do mineral waters cure diseases?
How does water evaporate and condense?
What water is pure?
What is the nature of water pressure?
How is the energy of water pressure secured and used in doing work?
What practical application is made of the fact that water cannot be compressed?

Problem IV–A · What are the Distribution and the Nature of Water?

Water on the earth. Nearly three fourths of the earth's surface is covered by the oceans. These are commonly spoken of as being separate. They are really all joined together, forming one great body of water which completely surrounds the continents. Their average depth is about two and one half miles. The volume of the ocean is almost fifteen times the volume of the land that is above the water. Thus if all the land above sea level were deposited in the ocean, the ocean level would be raised only about six hundred fifty feet. But if the land above the ocean and that beneath its surface were brought to the same level everywhere, the ocean water would then cover the entire earth to a depth of about 1.7 miles.

Distribution of water over the earth. In addition to the water of the oceans there are the lakes, rivers, and other bodies of water on the land. These bodies of water together, however, make up only a part of the water on and in the earth.

Experiment 9. Does dry soil contain water? Weigh a panful of the driest soil you can find. Heat it for an hour or so, but not hot enough to burn up any bits of wood or other similar matter which might be in the soil. Weigh it again. Did it lose weight as a result of the heating? Did the soil contain water before it was heated?

Martin Johnson

FIG. 34. Zebras and wildebeests at a water hole in a dry river bed in Africa. **Exercise on Scientific Method (Making Inferences[1]) :** What season of the year do you infer this to be?

Exercise on scientific method (inventing experiments). Do you think it possible that after heating the soil it may still contain some water? Can you suggest a further experiment by which you might find out?

Experiment 10. How can water vapor be condensed from the air? Hold a cold body, such as a piece of bright metal, above a beaker of boiling water. Observe the surface of the metal to see whether water collects on it. Blow your breath upon a cold mirror or a windowpane and see whether water is condensed from your breath. Make a statement of your conclusions.

We often hear the expression "as dry as a desert." This idea is common because many people think of a desert as the driest area which can be imagined. Many people think it is a place where there is no water except in an occasional spot (Fig. 34). There is no region on the earth where there is no water. Water exists even in the parts of the driest desert where there are no pools. It is in the air in the form of vapor. It exists in very small quantities within what seems to be the driest sand. Some water

[1] *Inference* (in'fer ence): a probable conclusion to which observations and known facts point but which they do not prove beyond question.

exists as a part of certain rocks and minerals. Ordinary alum, for example, is partly made up of water. If the alum is heated, it loses this water and becomes a dry, easily powdered substance.

What is water? Water is neither a simple substance, like oxygen, nor a mixture of several separate substances, like air. Let us see whether we cannot find what water is. First we must secure some hydrogen gas.

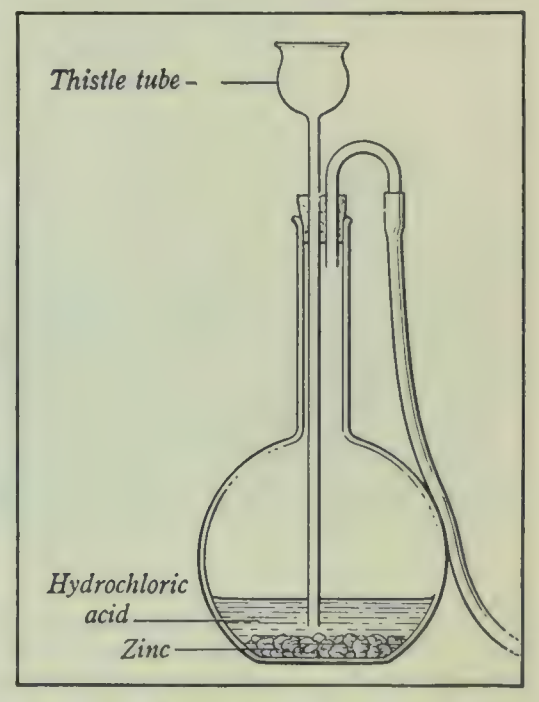


FIG. 35. A hydrogen generator. The first gas which comes from the tube is not pure hydrogen. Explain

Experiment 11. What are some of the characteristics of hydrogen? Put into a flask some bits of zinc or powdered iron. Add a drop or two of copper sulfate (blue vitriol) in solution. Arrange a thistle tube and a piece of bent glass tubing through the holes of a two-hole rubber stopper. Insert the stopper in a flask (Fig. 35). Attach to the end of the glass tube a length of rubber tubing sufficient to carry the gas generated in the flask to a pan of water, as in Experiment 4 (oxygen). Add dilute hydrochloric acid through the thistle tube until the end of the thistle tube is covered. The bubbles which rise from the zinc or iron are bubbles of hydrogen. Collect several bottles of hydrogen by the method used in collecting oxygen (Fig. 15, p. 29). Keep the bottles upside down to prevent the hydrogen from escaping. Note the color of the hydrogen. Place a glowing splint in a bottle of hydrogen. Does the splint burn? Place a lighted splint in a bottle of hydrogen. Does the hydrogen burn? Summarize in a statement all the facts that you have learned about hydrogen from this experiment. Collect another bottle of hydrogen by holding a dry bottle in one hand and thrusting the mouth of the tube from the hydrogen generator as far as possible into the bottle. Hydrogen is, volume for volume, the lightest known substance. Hence it will now rise in the bottle, forcing out the air as it did the water before. When you think the bottle must be full of hydrogen, first remove the tube, then hold a lighted match at the mouth of the inverted bottle. [CAUTION: *Be sure at all times to keep the end of the tube leading from the hydrogen generator well away*

from any flame.] Examine the inside walls of the bottle. Is there any substance now on the walls of the bottle which was not there before you burned the hydrogen in the bottle? Repeat the experiment with another bottle of hydrogen, collected in the same way, as a control. Be sure the bottle is *entirely dry* when you begin the experiment. Also be sure to keep the bottom of the bottle turned upward while you are collecting the hydrogen and are burning it. If you find a substance on the sides of the bottle, can you tell what it is?

Exercise on scientific method (using controls). How did the second bottle of hydrogen serve as a control?

Water is an oxide, as is carbon dioxide. Also, just as carbon dioxide is formed when a substance containing carbon burns, so is water formed when hydrogen burns. A correct though less familiar name for water is hydrogen oxide. When hydrogen is lighted as in Experiment 11, it burns quietly. But if hydrogen and oxygen are mixed and a flame or a spark is then introduced into the mixture, a violent explosion may result. When hydrogen oxidizes by burning, as in this experiment, the quantity of water formed is very small, because the gases, hydrogen and oxygen, occupy several hundred times as much space as the water which they form.

Self-test on Problem IV–A. (*Do not write in the book.*) **1.** Most of the earth's surface is covered with *land.*

2. *Few* regions of the earth are without any water whatever.

3. The earth has *little water except* that which is in the oceans, ponds, lakes, and rivers.

4. Hydrogen oxide is another name for *air.*

5. Hydrogen is oxidized to form *carbon dioxide.*

Problem IV–B · What are Some Important Properties of Water?

Water carries substances in solution. We are familiar with substances, such as salt and sugar, which dissolve readily in water. Other substances, such as rocks, dissolve in water to so slight an extent that usually we are not aware that they dissolve at all. Yet there are many substances which dissolve to some extent. In fact, more substances dissolve in water than in any other solvent.[1]

[1] *Solvent* (sol'vent): a substance in which another substance dissolves.

These substances include not only solids but liquids, such as alcohol and vinegar, and gases, such as air. Water animals, such as fish, breathe the oxygen that has been dissolved in water. In general, water will dissolve greater quantities of solid substances when it is hot than when it is cold. Also, in general, hot water will dissolve solid substances much more quickly than will cold water. Also, in general, water will dissolve smaller quantities of gases when it is hot than when it is cold. Thus we noted in Experiment 2, p. 20, that when the water became warmer it was unable to hold in solution so much air as before. Therefore some of the air which had been dissolved in the cold water came out of the water in bubbles as the water became warmer.

There are substances, however, which practically do not dissolve in water at all, though they may dissolve readily in other solvents. Thus, grease spots can be removed from clothing with carbon tetrachloride but not with water, because the grease dissolves readily in carbon tetrachloride but not in water.

Ocean water is a solution. It contains salt and small quantities of many other substances that are dissolved in the water. Water that is strictly pure is never found in streams or lakes. More or less mineral matter is always found dissolved in such water. In certain springs the water contains so much dissolved mineral matter that some of this matter is deposited in odd and beautiful shapes and colors (Fig. 36).

Mineral waters and diseases. In many parts of the world there are "mineral springs." These contain sufficient quantities of dissolved minerals to give the water a pronounced taste or smell, or both. The water from such springs is commonly thought to be especially healthful to drink. Many people pay high prices for "mineral waters" or for "crystals" supposed to be obtained from them, under the belief that mineral waters are natural medicines which will cure rheumatism, kidney disease, and other diseases. There is scientific evidence, however, which indicates that most natural mineral waters are probably no more healthful to drink and no more able to cure diseases than is ordinary water.

Water evaporates and condenses. Water evaporates more rapidly as its temperature is raised. Boiling is merely rapid evaporation. The vapor which results from the evaporation is

FIG. 36. Morning Glory Pool, Yellowstone National Park. **Exercise on Scientific Method (Making Hypotheses):** Can you suggest how these minerals came to be deposited on the sides and bottom of this pool?

invisible and mixes with the gases of the air. When the air is cooled sufficiently, some of the vapor condenses[1] and becomes visible again as tiny drops of water. Thus we see that evaporation and condensation are opposite processes.

When water is heated, bubbles appear at once upon the bottom and sides of the vessel. These first bubbles consist of air which was dissolved in the water when the water was colder but which cannot remain dissolved when the water is heated (see Experiment 2, p. 20). Some of the water is evaporating all the time; that is, some of the tiny particles called molecules are escaping from the surface of the water all the time. The hotter the water becomes, the faster it evaporates; that is, the more molecules escape from the surface. Finally the water reaches its boiling point. The molecules now escape not only from the surface but also from within the water, forming bubbles of steam. These steam bubbles are forced to the surface, because steam is lighter, volume for volume, than water. When this occurs the water is boiling.

[1] *Condense* (kon dens'): to change from a vapor or a gas to a liquid or a solid.

Can one see steam? We are apt to think that water evaporates only when in the liquid state, but ice and snow also evaporate to some extent. Water vapor is invisible. Nobody ever saw steam. One often hears people speak of seeing the steam from a locomotive whistle or from the spout of a teakettle. What they see is not the steam itself but the tiny drops of liquid (water) that are formed from the vapor (steam) when it has been sufficiently cooled by the cold air so that it condenses. You can prove the truth of this last statement by observing a teakettle in which water is boiling. You will see nothing immediately in front of the spout, but you will see a cloud of condensed vapor, like fog, an inch or so from the end of the spout. An explanation of this fact is that steam consists of molecules which are too small to be seen. When enough of them have been condensed into drops, the drops are easily seen.

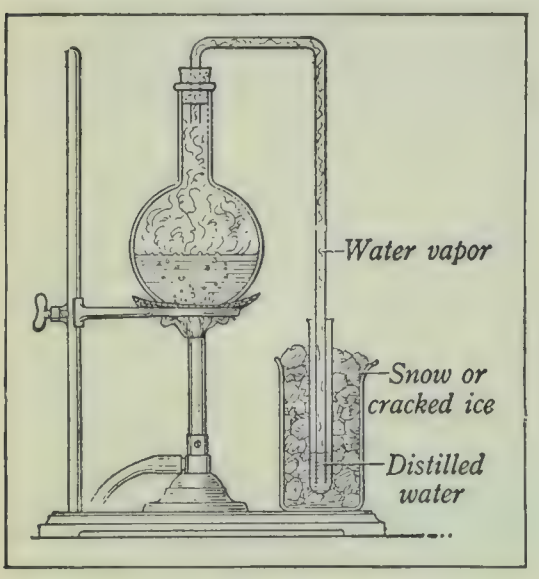


FIG. 37. Distilling water. **Exercise on Scientific Method (Inventing Experiments):** If no ice could be obtained, what might you use instead to cool and hence condense the vapor?

What water is pure? Pure solutions are always clear. Therefore we cannot tell from the appearance of water whether it is pure or a solution. But if a little of the water is evaporated, that is, boiled to dryness, any solids which were dissolved in the water will be left in the bottom of the dish.

Only distilled water is pure water, because when water evaporates, only the molecules of water form the vapor which later is condensed. All solid substances in the water are left behind when it evaporates. Distilled water is used by druggists, physicians, and chemists in their work. It is also used in automobile batteries.

Experiment 12. How can water be distilled? Put some soil, some sugar, and some salt into a flask partly full of water. Arrange the apparatus as in Fig. 37. Allow the water in the flask to boil for some time. Has

the distilled water in the test tube any color or any taste? Evaporate a little of the distilled water in a clean dish. Is any solid substance left in the dish when the water is all evaporated? To answer the question at the beginning of this experiment, copy the following sentence and fill each blank either with the word *condensing* or with the word *evaporating*: Water is distilled by __(?)__ it and then __(?)__ the vapor.

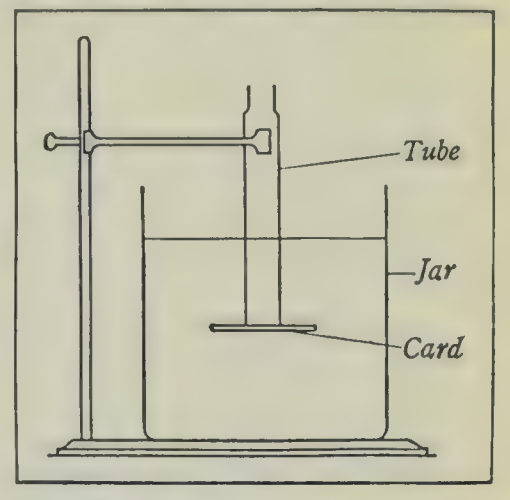


FIG. 38. Is there any pressure on the upper surface of this card? Justify your answer

Is water pressure like air pressure?

Experiment 13. Does water exert pressure upon surfaces which are under water? If so, how is this pressure increased? Fill a battery jar almost full of water. Put a *very little* grease or vaseline on one side of a visiting card. Then press the card over the end of a glass tube (a lamp chimney will serve) about one foot long and one or two inches in diameter, so that the card and the grease seal the tube watertight. Use only enough grease to make the seal watertight, but not enough to stick the card to the tube. Thrust the end of the tube down into the water so that the end which is covered by the card is about two inches below the surface. Clamp the tube firmly in this position (Fig. 38). What holds the card against the end of the tube? Slowly and carefully pour water down the inner wall of the tube. Note carefully the depth of water inside the tube at the moment when the card drops off the end of the tube. What caused the card to drop off the tube? Repeat the experiment with another card, forcing the lower end of the tube considerably deeper into the water. Repeating the experiment serves as a check experiment. Is it necessary? Was a greater or a smaller depth of water necessary in the tube before the card would fall off this time than the preceding time? Why is this true? Summarize the results of this experiment in one or two complete sentences.

Exercise on scientific method (isolating the experimental factor.) The experimental factor here is depth (see page 31). Explain.

If you have learned to dive, you are familiar with the fact that the pressure of the water increases as you go farther below the surface. The pressure in water, unlike pressure in air, increases

uniformly with the depth. That is, each foot of depth adds .43 pound on every square inch of surface. This is because a column of water one foot high and one square inch on the end weighs .43 pound. In the study of the caisson we learned that the pressure under water increases one atmosphere, or 15 pounds per square inch, for every 34 feet of increased depth. Therefore at the greatest known depth of the ocean, 34,210 feet, the pressure of the water is more than 15,000 pounds, or $7\frac{1}{2}$ tons, on every square inch of surface.

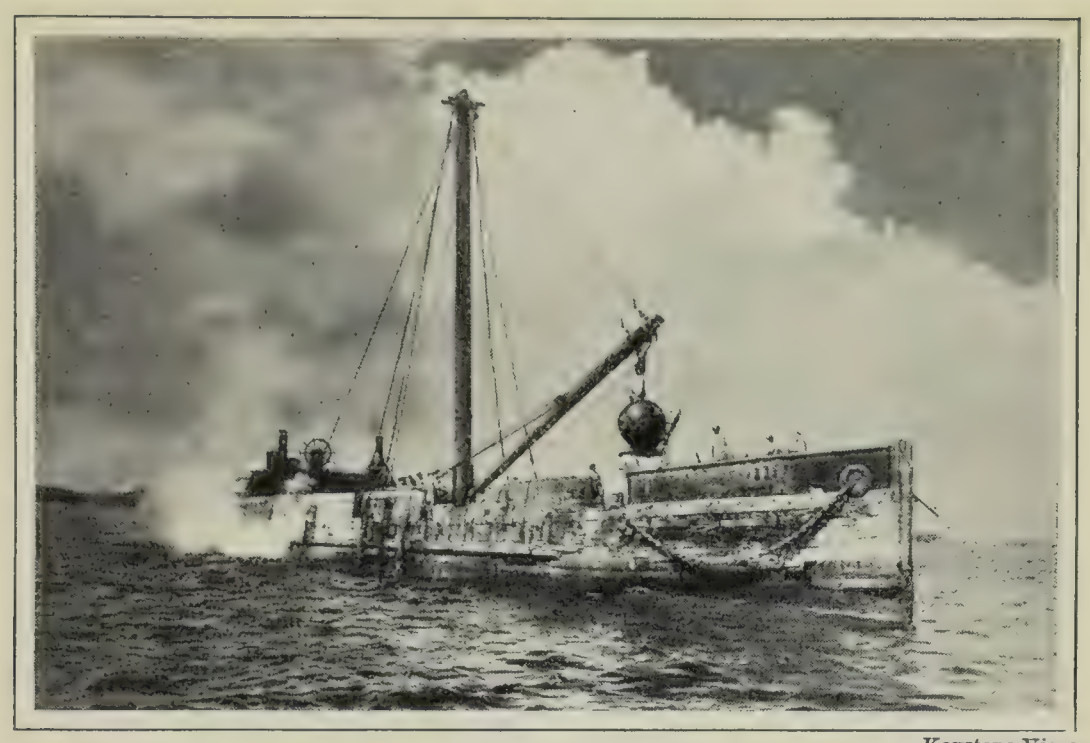
Exploration in great pressures. Because the pressure of water increases so rapidly with the depth, it has not been possible to explore the ocean far below the surface. Deep-sea divers in their diving suits seldom work at a depth greater than 60 feet. It is considered unsafe to work at a depth greater than 80 feet. Yet a record of 304 feet was reached at Honolulu in 1914, when Chief Gunner's Mate Frank Crilley investigated a sunken United States submarine.

Recently the American scientist William Beebe has been exploring the ocean in a steel ball (Fig. 39). On August 15, 1934, off the coast of Bermuda, he descended to a depth of 3028 feet in his "bathysphere." By these explorations Beebe not only has discovered some kinds of fish and other animals previously unknown, but also has been able to make important observations of underwater coast lines and deposits of materials washed from land into the ocean.

***Water pressure and energy.** Water pressure is an important source of energy. There are hundreds of waterfalls along the streams in the mountainous regions of the United States and Canada. These are capable of being developed into enormous sources of energy, usually called water power. Dams are often built at the lower ends of valleys to raise the level of the water and thus increase its stored energy. They are also built at the lower ends of river valleys to form artificial lakes in which to collect and store vast quantities of water for water supply and irrigation.[1] The dam is usually constructed of concrete reinforced[2] by means of steel bars, which run through the concrete, thereby

[1] *Irrigation* (ir i ga'shun): watering land by artificial means.

[2] *Reinforce* (re in fors'): to make stronger; to add strength to.



Keystone View

FIG. 39. The bathysphere in which Beebe and his companion explored beneath the ocean surface is the round object. While under water Beebe described by telephone what he saw through the quartz windows, to an assistant on the boat, who wrote the descriptions in shorthand. Beebe's companion, Otis Barton, took moving pictures and photographs through the bathysphere window. Why is Beebe able to descend in safety in his bathysphere to so much greater depths than would be possible in a diving suit?

greatly increasing its strength. Sometimes the dam is built so that it curves upstream. Why? The dam is made much thicker at the bottom than at the top. With its weight thus mostly at the bottom, it can withstand much greater pressures than if its walls were of the same thickness throughout. Why?

The pressure below the surface of water depends only upon the depth of the water and not upon how great the area of water may be (Fig. 40). Thus the pressure which water exerts against the wall of a dam 34 feet below the surface is 15 pounds per square inch, no matter whether the lake extends a hundred feet behind the dam or a mile. Also, like air, water at any point exerts the same force in every direction.

Water cannot be compressed. Some football players can kick a football sixty yards. This is possible because the air in the football is instantly compressed when the kicker's toe strikes the

ball. Thus the compressed air pushes against the toe, forcing the football away from the foot. If the football were filled with water,

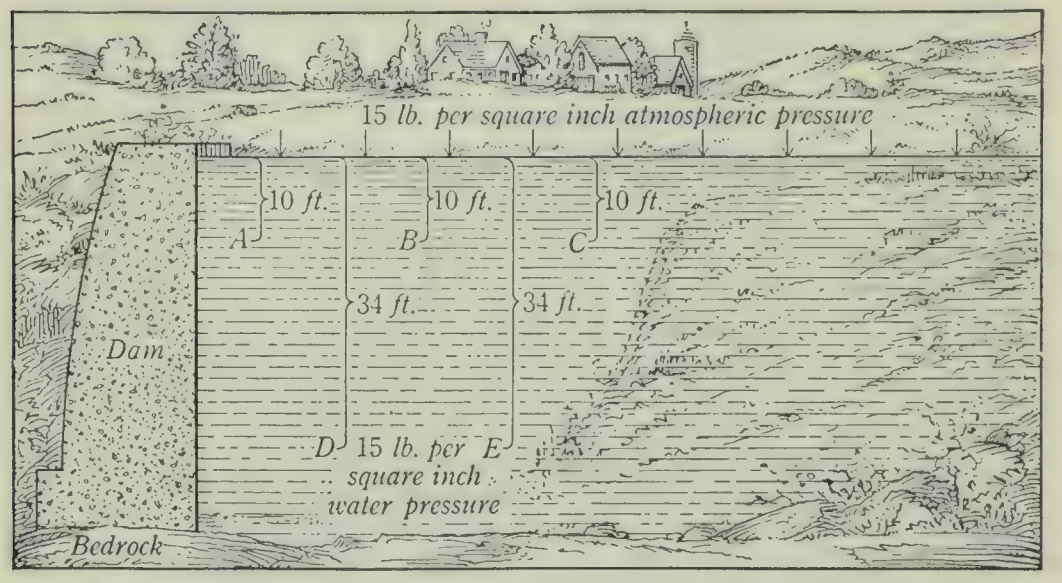


FIG. 40. The pressures at *A*, *B*, and *C* are equal. Why? Why is the *total* pressure at *D* and *E* not 15 but 30 pounds per square inch? If enough of the river bed behind the dam were removed to double the quantity of water stored, would the pressures at *A*, *B*, and *C*, or at *D* and *E* be changed? Explain

however, it could not be kicked more than a few feet, not only because water is heavier, volume for volume, than air, but chiefly because water cannot be compressed like air. Scientists have learned to make many useful applications of the fact that water cannot be compressed, just as they have learned to make use of the fact that air can be compressed.

If pressure is applied to water or oil which is confined within a vessel so that it is not able to escape, the pressure is transmitted[1] through the water or oil in every direction without loss. Thus, if a bottle entirely filled with water were closed with a cork, of which the end against the water was one square inch in area, and if then you struck the cork a fifteen-pound blow, the result would be the same as if you had struck a fifteen-pound blow against every inch of the inside of the bottle. The water would transmit the force without loss to every square inch of the enclosing bottle. Consequently the bottle would be broken.

***Action of the hydraulic press.** The hydraulic press (Fig. 41) is a practical application of the facts just explained. The action

[1] *Transmit* (trans mit′): to send across or through.

of the piston and the valves is very similar to that of the force pump. When the small piston is pulled upward, valve *a* is forced shut by the pressure of the water and the weight of the large piston pressing on the water above it. Valve *b* is forced open by the pressure of the water from the supply pipe. When the small piston is pushed downward, valve *b* is forced shut and valve *a* is forced open. The water transmits the force from the small piston to the large piston without loss. Thus let us suppose that the small piston has an area of one square inch, and the large piston an area of twenty-five square inches. The force exerted upward against the large piston will be twenty-five times as great as the force exerted downward by the small piston, because the larger piston is twenty-five times as large as the small one.

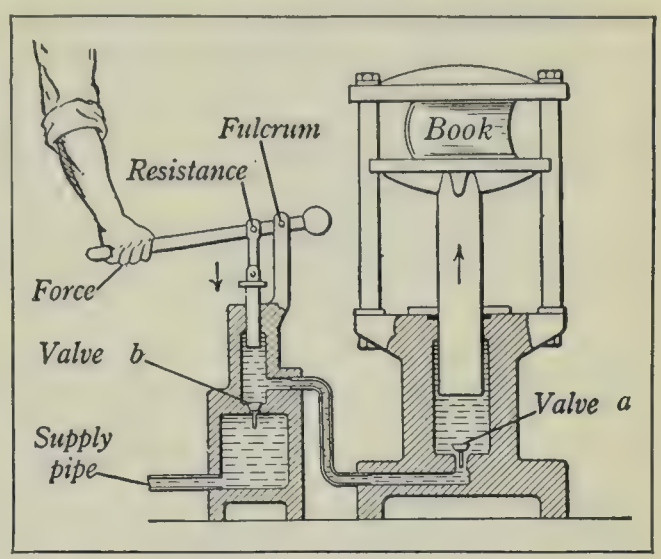


FIG. 41. A hydraulic press compressing a dictionary. Would air serve as well as oil or water in a hydraulic press? Explain

Hydraulic presses are used for compressing paper and cotton bales, for raising and lowering dentists' and barbers' chairs, for pressing oil out of seeds, for punching holes in iron plates, and for various other purposes. Hydraulic presses have been constructed of such size that one large press can exert a force of twenty million pounds.

In some makes of automobiles hydraulic brakes are used. A hydraulic brake is a hydraulic press in which the force applied by the foot is transmitted through liquid to each brake.

Self-test on Problem IV–B. (*Do not write in the book.*) **1.** Goldfish are likely to have a *more* abundant supply of air when the water is warm than when it is cool.

2. *All* substances dissolve readily in water.

3. The use of mineral waters and crystals may *usually* be expected to cure serious diseases of many sorts.

4. As the temperature of water is raised greater quantities of it *condense.*

5. The only water that is perfectly pure is *spring* water.

6. If the area of a swimming pool were doubled while the depth of water were kept at ten feet, the pressure on the bottom would be (1) just the same as before; (2) slightly greater; (3) twice as great; (4) two atmospheres; (5) half an atmosphere.

7. The hydraulic press is able to operate as it does because *oil* and *air* cannot be compressed.

Problem IV–C · How is the Energy of Running Water Used in Doing Work?

***Running water does important work.** When it rains, the water flows from higher ground to lower ground. This drainage[1] of water from higher to lower levels is due to gravity, which is the attraction of the earth for all bodies upon or near it. Thus because of gravity the water runs off the hillsides into the valleys, thence down the valleys, forming streams always flowing downward toward the ocean. Wherever the valley widens and the current becomes sufficiently slow, the stream, if large enough, spreads out and forms a lake.

*As the streams flow downward to the ocean, the running water does important work in moving soil and rocks from the hills into the valleys and finally to the ocean. Men use running water to do such work as transporting logs, boats, and rafts to places downstream, and to turn water wheels which run mills and generate[2] electric currents.

***Simple types of water wheels.** The earliest types of water wheels were the overshot wheel and the undershot wheel. These types are still used somewhat, though they have been largely replaced by the Pelton wheel and the water turbine. The overshot wheel is used where the stream beds slope steeply but the streams do not carry a great volume of water. It cannot be used in flat countries. A dam is built across a stream to raise the water

[1] *Drainage* (drain'aj): the flowing of water from higher to lower levels; also the liquids which drain off.

[2] *Generate* (jen'er ate): to produce or cause to be made.

level enough so that a large tube or flume can carry it to a point just above the wheel (Fig. 42). This type of wheel is turned chiefly by the weight of the water on the blades as the water falls. It makes use of most of the energy of the water falling over it.

The undershot wheel (Fig. 42) is used where there is a great volume of water with but little fall. This wheel is turned by the pressure of the water as it flows against the blades. The undershot wheel makes use of only a relatively small part of the energy of the running water, since most of the water flows uselessly under or around its blades.

In places where the water can be dammed up only a few feet high a breast wheel is sometimes used. This combines some features of both the overshot and the undershot wheel (Fig. 42).

***The Pelton wheel.** The Pelton wheel (Fig. 43) is a special form of undershot wheel. It is used where a small quantity of water under high pressure can be had. The water is brought to the wheel through a pipe and is directed against the cup-shaped blades of the wheel. The Pelton wheel finds wide use in small power plants in cities that have water works, and also for great power plants in mountainous

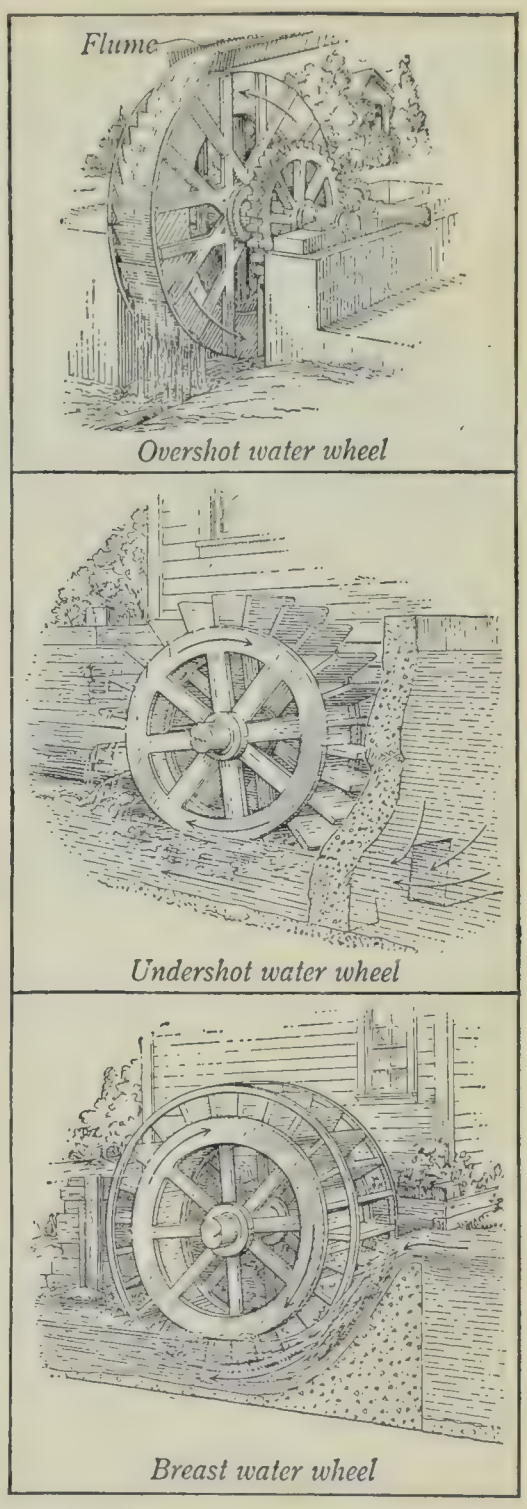


FIG. 42. Three common types of water wheel used to change the energy of running water to the energy of turning wheels. What are the advantages and disadvantages of each type of wheel as compared with the others?

regions where the water can be brought from considerable heights. In the Big Creek development in California, water flowing from reservoirs[1] 2130 feet higher than the power plant is delivered through a 6-inch nozzle against each of three Pelton wheels about 10 feet in diameter. Each Pelton wheel can develop 43,000 horsepower.

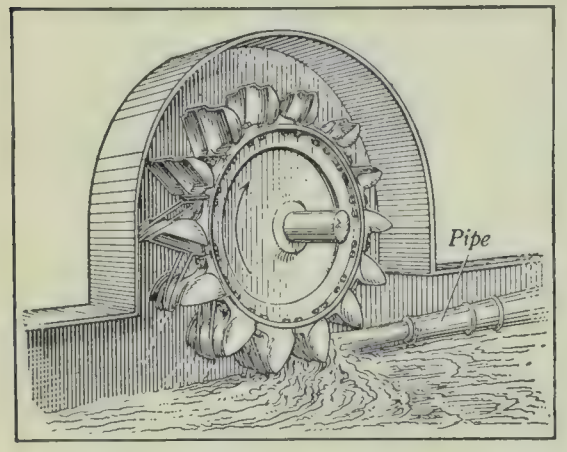


FIG. 43. The Pelton water wheel. Why does this type of wheel make very much better use of the energy of running water than the undershot wheel does?

*__The turbine.__ The water wheel which is most widely used is the turbine. It makes the best use of the energy of the flowing water. It is used for power developments where great quantities of water can be obtained but where the height of the reservoir above the turbine, and consequently the pressure, is not great. The water flowing through the pipe is directed against the curving blades of a horizontal[2] wheel which is completely under water (Fig. 44, *A*). The largest turbines in the world (Fig. 44, *B*) are at Niagara Falls. In one plant the water strikes a wheel 15 feet in diameter after dropping a vertical distance of a little more than two hundred feet. Each of three turbines in this plant generates 70,000 horsepower. Another plant at Niagara Falls is capable of developing 450,000 horsepower.

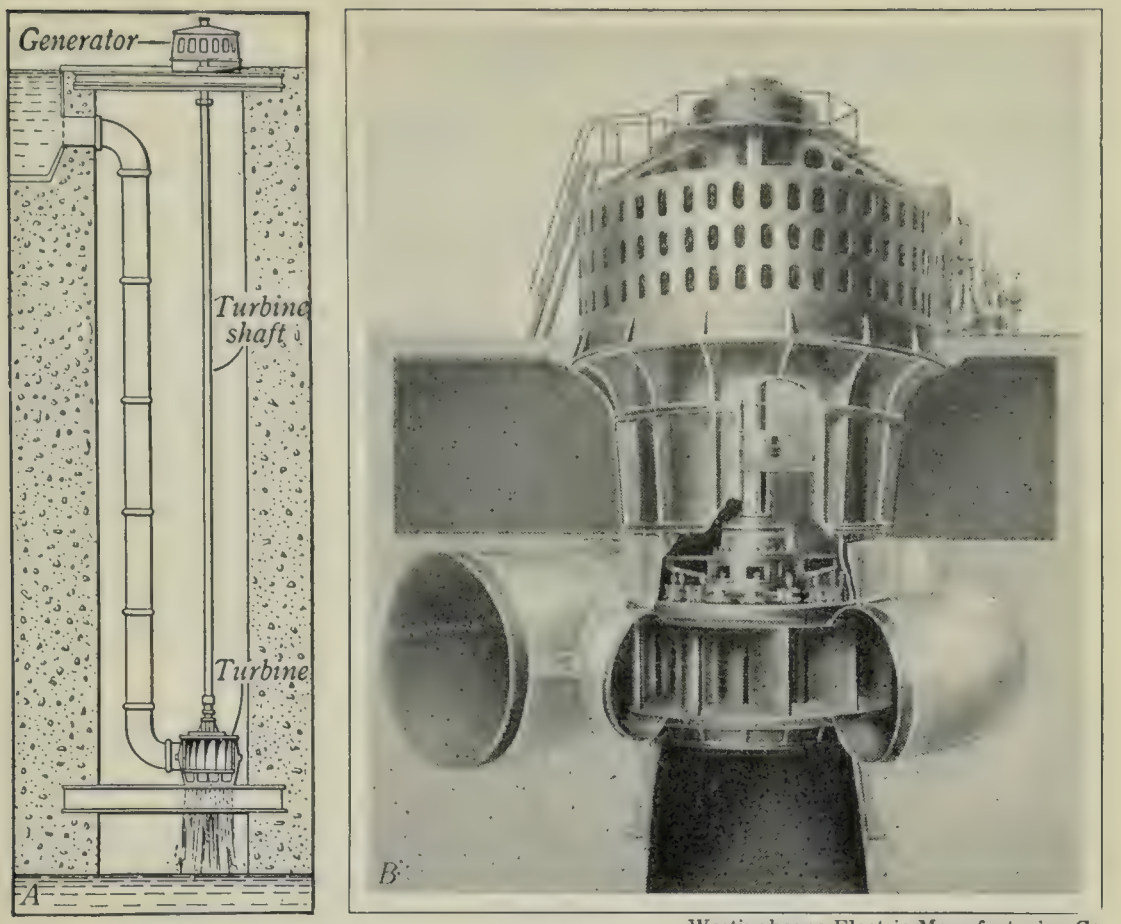
Self-test on Problem IV–C. (*Do not write in the book.*) 1. The energy of running water is of *small* importance in industry.

2. The type of water wheel which makes the best use of the energy of flowing water is (1) the overshot; (2) the breast; (3) the undershot; (4) the turbine; (5) the Pelton.

3. A more efficient form of undershot water wheel than the simple undershot wheel is the __(?)__.

4. The overshot water wheel is likely to find its widest use in *flat* country.

[1] *Reservoir* (rez'er vwor): a place where water is collected and stored.
[2] *Horizontal* (hor i zon'tal): level, like the horizon.



Westinghouse Electric Manufacturing Co.

FIG. 44. *A*, diagram of a water turbine; *B*, diagram of the highest-powered turbine in the world. The water flows entirely around the wheel. Of what value is this feature?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What substances can you name that do not dissolve readily in water?

2. Why is distilled water used by druggists and physicians in their work? Why is it used in automobile batteries?

3. How is it possible for clothes to freeze dry in winter?

4. Why do large dams need to be built on bedrock?

5. Two lakes are connected by an underground stream. If a fish swims from one lake to the other, keeping always at a depth of 34 feet below the water level in the lakes, where will it be under greatest pressure? Explain. How much will the pressure on it be in pounds per square inch and in atmospheres? Explain.

6. If put into freshly distilled but cool water, fish would be uncomfortable and might die; but if the water were first sprayed into the air

or allowed to drip or fall in a fine stream through the air, the fish would be comfortable in it. Explain.

Exercise on Scientific Attitudes. After the following problem you will find five statements. See whether you can pick out the one which a carefully trained scientist would consider best. Then see whether you can find which of the scientific attitudes (pp. 12 and 13) is illustrated by the best answer.

Some years ago a famous traveler, whom the great scientists considered a careful and accurate observer, reported that he had found in South America a bird which had a head somewhat like that of a lizard and a tail somewhat like that of a parrot, and which cracked and ate nuts. Nobody else had ever reported having seen or heard of such a creature.

a. I will not believe the account until I have seen the bird.

b. The account might possibly be true, but is not very likely to be.

c. It couldn't possibly be true.

d. It might be true, and probably is if a careful and accurate observer reported it.

e. There can be no doubt whatever that it is true, because careful and accurate observers do not make mistakes.

Project. To construct of thin boards, such as shingles or cigar boxes, and halves of tin cans or other pieces of tin, water wheels with which to demonstrate overshot, undershot, breast, and Pelton water wheels.

Special Reports. 1. What industries are located at Niagara Falls?

2. What is the available water power of the United States and of Canada? (Consult bulletins of the Departments of the Interior of both countries.)

3. Describe one of the great power projects which the United States government has developed during the past ten years.

Question for Debate. *Resolved*, That water pressure is of more importance to modern civilization than air pressure.

Books for Reference

Fisher, E. F. Resources and Industries of the United States. Ginn and Company, Boston.

World Atlas of Commercial Geology, Part II. United States Geological Survey.

Chapter V · Securing a Water Supply

Questions this Chapter Answers

What are the sources of water in the country and in the city?
How is running water supplied in country homes?
How is water distributed in the city?
What kinds of impurities make water unsate to drink?
How may one learn whether the water supply is safe to drink?
How is impure water rendered safe to drink?

Problem V–A · What are the Sources of the Water Supply?

Water a necessity and a luxury. Many of us are so accustomed to having all the water we want for every purpose by simply turning a faucet or by going to the well or pump that it is difficult for us to imagine life in homes which are not sufficiently supplied with water. In colonial times one well, which was located in the middle of the village, supplied all the people. This method is still in use in villages of some foreign countries. In Nazareth, for example, some of the wells of Bible times are still supplying water (Fig. 45). In some of the largest cities of China the water is provided by wells. It is carried by the people who are to use it, or is distributed in wheelbarrow water wagons from house to house.

Should we be likely to use as much water as we do if all that we use for our various household purposes had to be carried or wheeled from a distance?

Ground water. Rainfall is the source of all water supply. Because of gravity [1] water not only runs downhill on the surface of the ground in streams, but also sinks into the ground, forming the ground water. Ground water sinks readily through layers, or strata, of porous materials, such as sand and gravel, until it reaches bedrock. It then collects above the nonporous bedrock,

[1] *Gravity* (grav'i ty): the attraction any body has for any other body, but especially the force that pulls objects to the earth.

FIG. 45. At Mary's well in Nazareth, Palestine. The water flows from an opening in the ground behind the woman with the water jug. What advantages and what disadvantages does this water supply have?

saturating[1] a layer of soil, that is, making it as full of water as it can be (Fig. 46). The top level of this saturated layer is called the water table. During the rainy season the water table is nearer the surface of the ground than it is during the dry season.

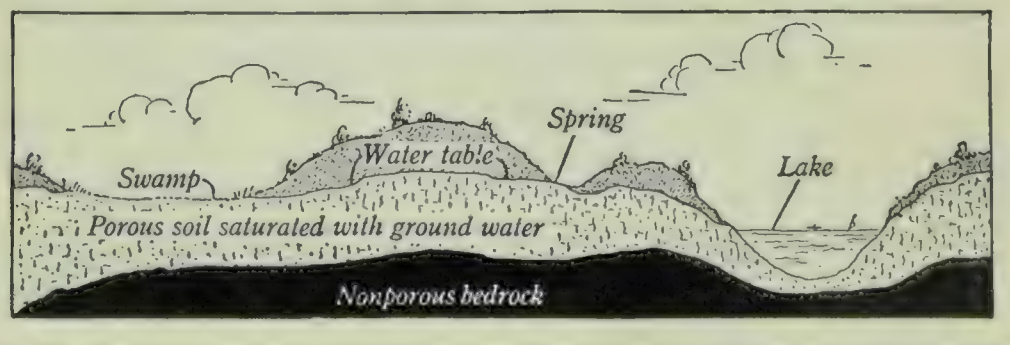


FIG. 46. Springs, swamps, and lakes are formed when the water table reaches the surface. Under what conditions would the spring and the swamp disappear? Under what conditions would the swamp become a lake?

The ground water flows downward along the surface of the bedrock. If the water table reaches the surface on a slope at a

[1] *Saturate* (sat'u rate): Anything is saturated with a substance when it holds within itself as much of the substance as possible. Thus, a sponge is easily saturated with water.

point lower than its general level, a spring results (Fig. 46). The water flowing from the spring forms a brook. Many such brooks

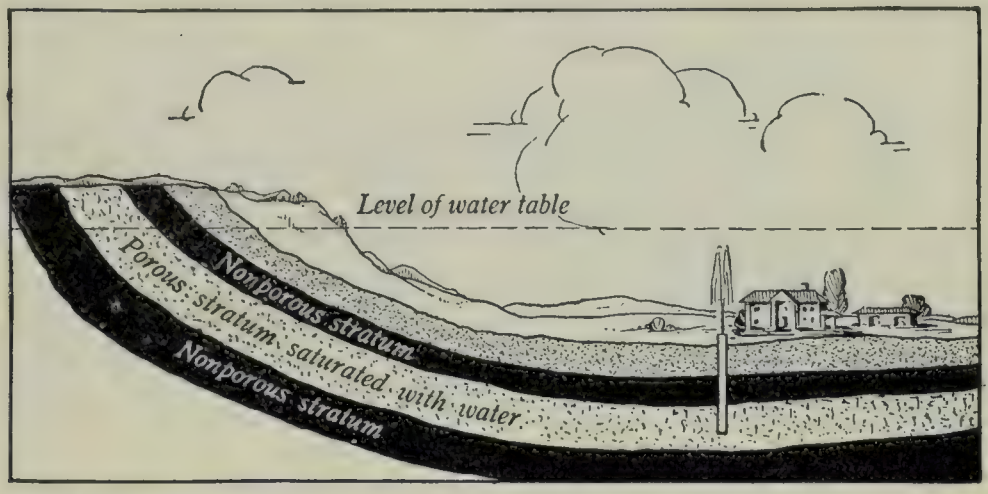


FIG. 47. An artesian well is possible only where there are sloping strata. Would the artesian well spout higher or less high after a long period of dry weather? Explain

unite to form streams and rivers. If the water table barely reaches the surface of the ground over a considerable area, a swamp is formed. If it reaches well above the ground over a considerable area, a lake is formed.

*Artesian wells. In some mountainous regions there are places where porous layers, or strata, of gravel or rock are found between nonporous strata of rock. These strata may all be folded so that in some places the porous stratum, or layer, is exposed to the rainfall. The water is then prevented from escaping to the surface and may be imprisoned beneath the valley floor miles away. Where the water table is considerably higher than the valley, as in Fig. 47, the pressure of the imprisoned water is great. If a hole or well is bored through the nonporous stratum of rock above this imprisoned water, the water "spouts out," sometimes to a considerable height. Such a flowing well is called an artesian well. Sometimes the pressure forces the water through cracks in the nonporous stratum to the surface of the ground, forming a natural artesian well.

Public control of city water supply. In the country the usual sources of water supply are wells, springs, and streams. Usually each family must secure its own water supply. In the cities, how-

C. E. Oliver

FIG. 48. The water supply of Portland, Oregon, is Bull Run Lake near Mount Hood. How many reasons can you give why this is unusually pure water?

ever, the water supply is usually under public control. Small cities sometimes can secure all the water they need from wells or springs. Often such sources do not furnish sufficient quantities for drinking, fire-fighting, disposing of sewage, sprinkling lawns and streets, and for many other purposes. An ample supply can usually be secured from a lake or river near by, or, in some cases, from a mountain lake or stream many miles distant from the city (Fig. 48). Cleveland and Buffalo, for example, secure their water from Lake Erie, and Chicago and Milwaukee from Lake Michigan. St. Louis obtains its water from the Mississippi River. Los Angeles and New York City are able to secure a sufficient quantity of pure water only by bringing it from distant mountain regions. The Los Angeles and New York City systems are gravity systems; that is, the water flows into these cities from sources above them because of the pull of gravity. The Cleveland, Buffalo, Chicago, Milwaukee, and St. Louis systems are not gravity systems, because the sources of water are below the cities. Therefore the water must be raised by pumps to the levels of the cities.

The Los Angeles water system. The Los Angeles and New York City water systems are of especial interest. Los Angeles obtained its original water supply from the Los Angeles River at a point conveniently near the heart of the city. Since this supply was sufficient for only about half a million people, additional

sources had to be provided for the rapidly growing population. In 1914, therefore, Los Angeles purchased a tract of land in the high Sierra Nevada mountains, where a great artificial lake was made by damming the Owens River. Later this Owens River system had to be extended in order to furnish enough water when the city should have a population of two million people. The continued growth of the city has made it necessary to seek still further sources of water. Los Angeles is now constructing a water-supply system which will be recognized as one of the greatest in the world. Its cost will total about $200,000,000, and it will furnish water for a population of seven and one-half million. The water will be brought from Parker Dam, which is about one hundred fifty-five miles downstream from Boulder Dam on the Colorado River. Parker Dam is about three hundred miles from Los Angeles — more than a hundred forty miles farther than the distance which New York City brings water from the Catskill Mountains. The water is led from the river into a reservoir twenty miles long, where the solid particles settle. It then enters a great pipe, or conduit,[1] eighteen feet in diameter and made of steel and reinforced concrete. The water is pumped through this huge main over mountains that are hundreds of feet higher than the river source, through 241 miles of main conduit, 154 miles of distribution trunk lines, 91 miles of tunnels (one of these being 18 miles long), 65 miles of lined canals, and 27 miles of steel siphon. Many reservoirs are being built along the way to keep an even supply of water. With this system Los Angeles may put to useful purposes water that has been wasted and that has even done great harm by floods. The building of this system is one of the greatest engineering feats since the building of the Panama Canal. When all its parts are in use, it will be capable of supplying to the city about a billion gallons of water per day.

The New York City water system. In 1842 the increasing need for large quantities of water forced New York City to build a huge reservoir on the Croton River, nearly fifty miles away. This supply was sufficient until about 1890. More water was then secured by extending and enlarging the Croton system. It soon

[1] *Conduit* (kon'dit): a tube or pipe through which liquids flow or electric wires run.

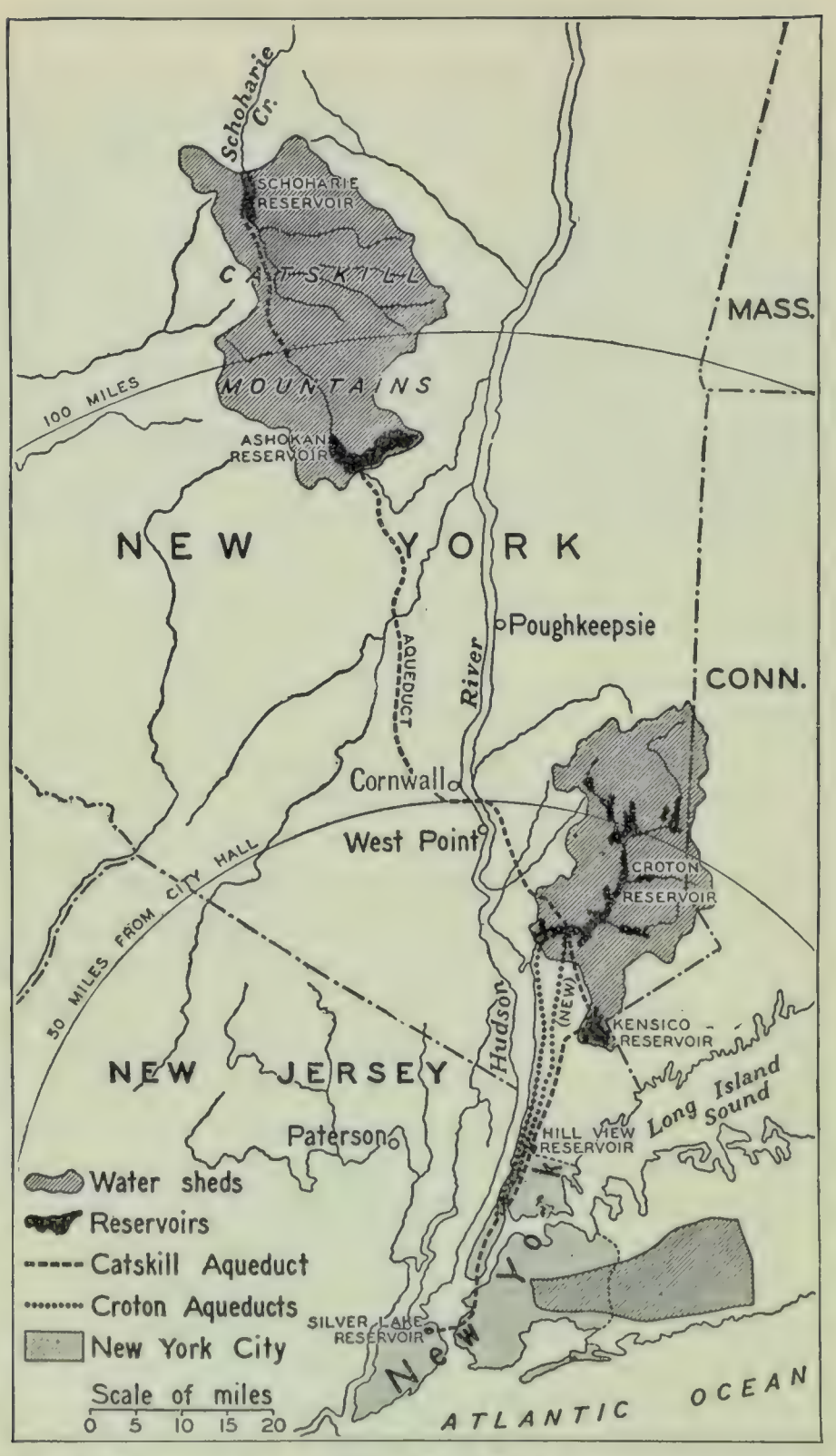


FIG. 49. Diagram of part of New York City's present and proposed water system. How is this water likely to be better for household purposes than water taken directly from the Hudson River?

became evident, however, that still further sources of water must be obtained in order to supply the needs of the rapidly growing city. First the Ashokan and later the Schoharie reservoir were constructed in the Catskill Mountains (Fig. 49). Croton, Ashokan, and Schoharie reservoirs occupy together nearly a thousand square miles. It is not surprising, therefore, that several towns had to be removed from the land which these reservoirs now cover. The water from the Schoharie reservoir is brought more than a hundred miles. Concrete conduits about seventeen feet in diameter, partly buried, carry the water to Cornwall. Here it passes under the Hudson River through a siphon cut through solid rock a thousand feet below the river. This water is stored just north of New York City in a reservoir of nine hundred million gallons capacity. From this reservoir the water is distributed throughout the city by conduits several hundred feet below ground. This water supply, which cost more than $200,000,000, provides an average of more than a hundred gallons a day for every person and is believed sufficient for the needs of more than eight million people. Even so, New York and other neighboring cities are already planning large extensions of the supply of water from the upper part of the Delaware River in eastern Pennsylvania and northern New Jersey.

Self-test on Problem V–A. (*Do not write in the book.*) **1.** The level of water in a well (1) bears little relation to the water table; (2) is the same as the water table; (3) is below the water table; (4) is somewhat above the water table; (5) is usually higher in late summer than in the spring.

2. The water table is *usually* very near the surface of the land in a desert.

3. The water that flows out of artesian wells fell as rain in the (1) mountains; (2) valleys; (3) rivers; (4) ocean; (5) lakes.

4. *Large* cities sometimes are able to secure their entire water supply from springs.

5. A spring or lake is not possible unless the water table is somewhat *below* the surface of the ground.

6. There are *few* swamps in country where the water table never reaches the surface of the ground.

7. The ground water *usually* remains *above* the nonporous bedrock.

Problem V–B · How is the Water Supply Distributed to our Homes?

Running water in rural homes. In past times country dwellers were satisfied with their water supply if they had a lift pump or a

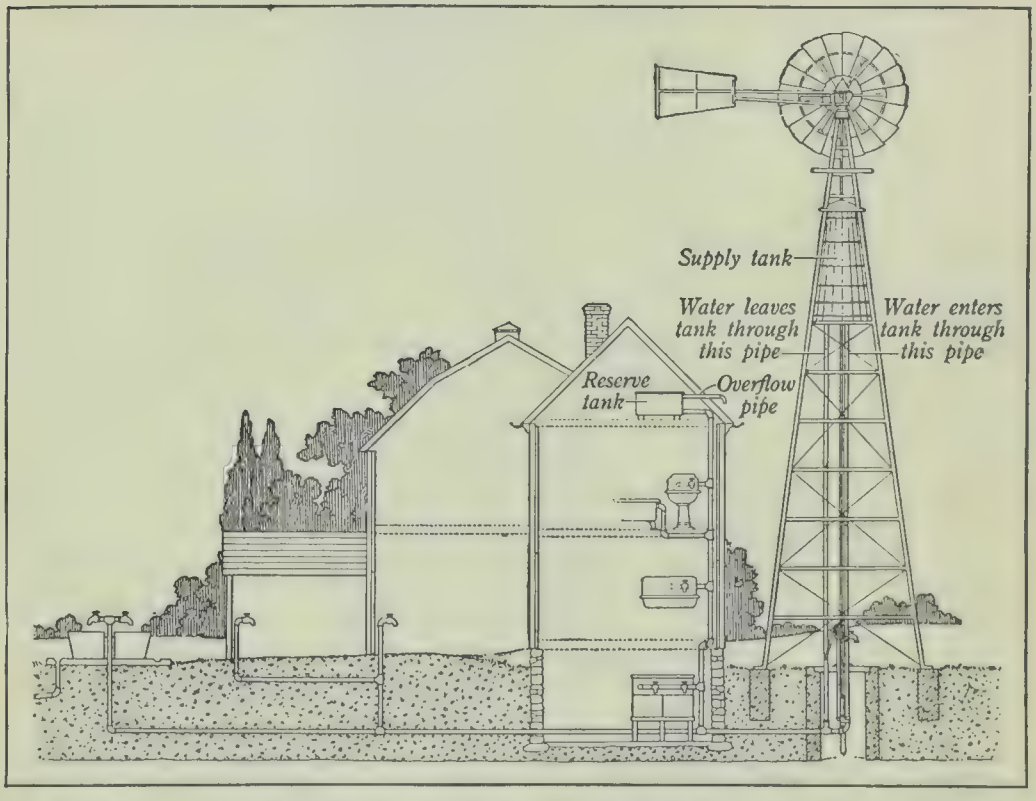


FIG. 50. An up-to-date rural water system. When the wind fails, the hand pump may be used. A device in the pump permits the water to be pumped directly into the supply tank, into the reserve tank, or to the barn. Why is the supply tank higher than the house?

well near the kitchen door. Today an increasing number of progressive farmers and ranchers are securing the same conveniences of running hot and cold water as are found in modern city homes.

*__Providing the needed pressure.__ Before water can be made to flow from faucets on the top floor of the house, however, the water in the pipes must have considerable pressure. In rural homes this pressure may be produced conveniently in three ways: (1) by damming a mountain spring to form a reservoir high enough above the house so that the water will flow by gravity to all the floors of the house; (2) by constructing a tank which holds a sufficient

supply of water at a level above the highest faucet in the house, to insure a similar gravity flow; (3) by installing a compressed-air

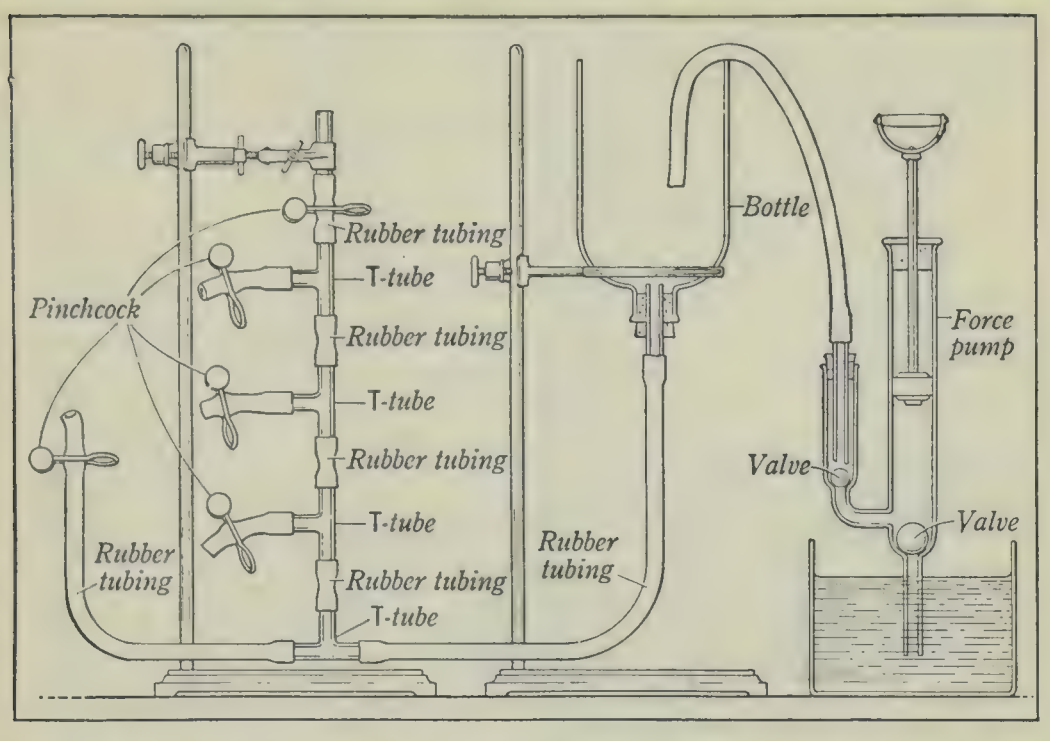


FIG. 51. A model water-supply system. How does this model force pump differ from that in Fig. 31, p. 51?

water system with which the water may be forced to the pipes on the upper floors of the house by compressed air.

*Using a force pump. A force pump is commonly used to lift water into a tank located outside the house or on the roof or in the attic. The pump may be operated by a small gas engine, or the wind may furnish the energy to turn a windmill (Fig. 50) so constructed that it moves the piston of the pump up and down.

Experiment 14. How may a model water-supply system be made? Remove the bottom from a large bottle by cutting with a glass-cutter around the bottle just above the bottom, then striking the edge below the scratch a sharp blow. Set up the model according to Fig. 51. The model represents the pump which forces the water into the supply tank (the bottle). The rubber tubing represents the water pipes. The pinchcocks represent faucets in a house.

When the model system is ready, pump the supply tank full of water. Open the faucets (pinchcocks). Can you observe any difference in the force with which the water flows from them? If there is a difference, how do you account for it?

***The compressed-air system.** Fig. 52 shows the construction of a compressed-air water system. Water is forced by a force

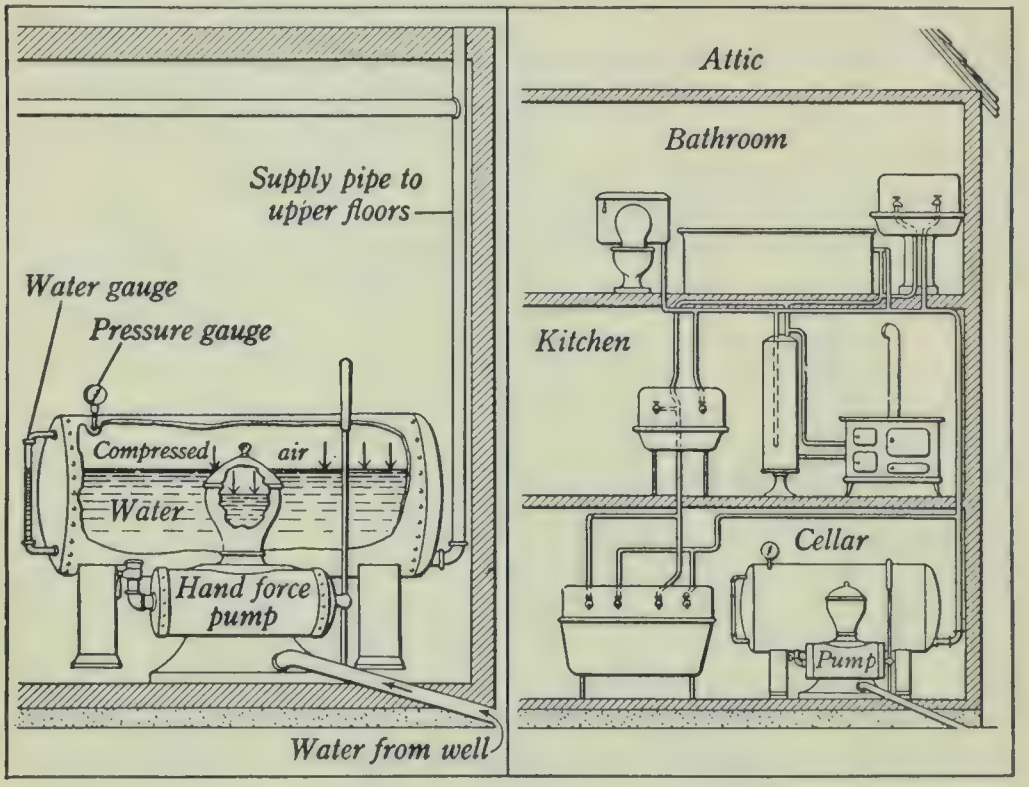


FIG. 52. A compressed-air water system. In what parts of this water system is compressed air being used? What advantages have this force pump and that shown in Fig. 31, p. 51, over the type shown in Fig. 51?

pump into the tank. As the water level rises in the tank, the air confined above the water is crowded into a smaller space. Hence its pressure is increased, just as it is in the dome of the force pump. The pressure gauge indicates when sufficient pressure has been produced in the tank to force water through the pipes to the upper floors of the house. The force pump is then stopped. When a faucet is opened in any part of the house, the compressed air in the tank forces water to flow out of the faucet. As the water in the tank is used, however, the air pressure in the tank becomes less, because the air expands to take the place of the water which is pushed out of the tank. Consequently more water has to be pumped into the tank for two reasons: (1) to maintain a sufficient air pressure and (2) to provide an abundant supply of water for all household purposes.

Distribution of water often difficult. In towns and cities the water is distributed through mains. In some small cities the water is pumped from wells or a river directly into the mains. In small cities where the water is secured from a river or a lake the surface of which is below parts of the city, however, reserve supplies of water are commonly pumped into tanks or standpipes (Fig. 53). Usually, especially in large cities, the water is stored in huge reservoirs that are built across mountain streams or in the highest parts of the city. From these the water flows by gravity directly through the mains and to the tops of the buildings. In large cities, when necessary, the water is forced through the mains by powerful force pumps. In some cities, however, these pumps cannot force water to the tops of the tall buildings. They cannot supply sufficient water at all times even for ordinary purposes and especially not for extra demands, such as fires. In such cities water is commonly pumped from the mains by smaller force pumps to tanks on different floors and on the roofs of the tall buildings.

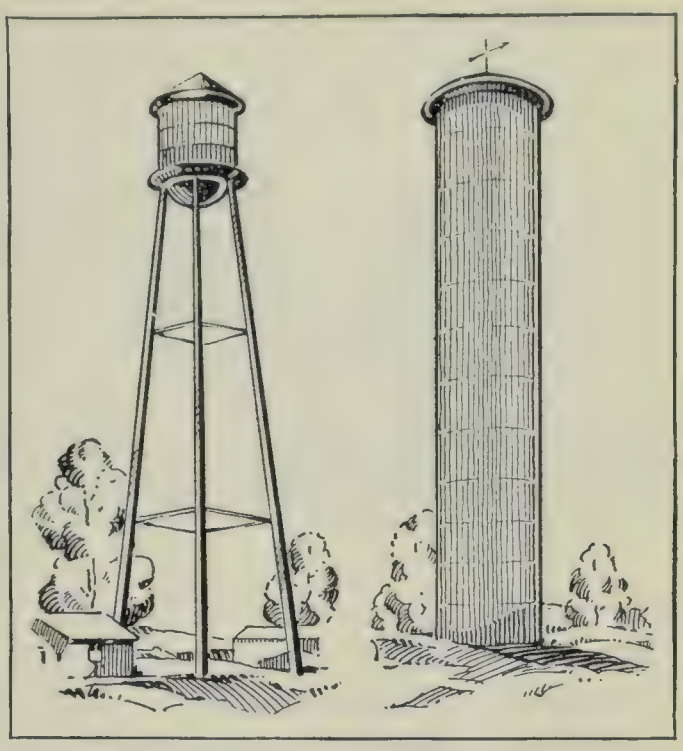


FIG. 53. A tank and a standpipe. Compare the advantages and disadvantages of these two methods of storing water

*Faucets. The screw, or compression, type of faucet (Fig. 54, *A*) has come to be the standard type for use in homes. A screw in the upper part of the faucet raises or lowers the handle rod as the handle is turned. A round leather or fiber washer is attached to the bottom of the handle rod. The faucet is opened by turning the handle so as to raise the washer from the opening, thus allowing water to flow out.

If a faucet is left open, much water is wasted. To prevent such waste, a self-closing faucet of the type shown in Fig. 54 *B* is used in public buildings. The handle rod is equipped with a spring which is compressed[1] when the faucet is opened. When the handle is released, the energy of the compressed spring forces the handle rod down, shutting off the water.

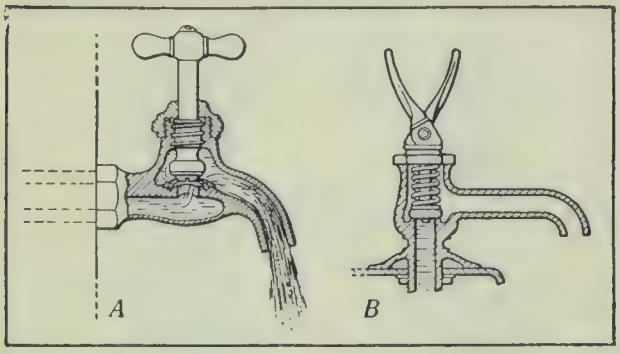


FIG. 54. Two types of compression faucet. What are the relative advantages of the meter plan and the flat-rate plan of paying for water that is used?

A leaky faucet should be repaired at once, since even a slow drip may waste several gallons of water in a day. Usually the leak is caused by the wearing out of the washer or of the packing around the handle rod. It is not a difficult task to shut off the water from the faucet, screw off the faucet, and put on a new washer or make the packing tight.

Self-test on Problem V–B. (*Do not write in the book.*) 1. Water can be forced from a tank in the basement to faucets in the upper part of the house by *gravity flow.*

2. Water will flow from faucets in the house provided the faucets are *lower* than the reservoir or tank in which the water is stored.

3. In a compressed-air water system, the higher the faucets above the tank the *greater* must be the pressure in the tank.

4. The *less* air is compressed in the tank of a compressed-air water system the *less* is its energy.

Problem V–C · How is the Water Supply Made Safe for Drinking?

The water supply must be pure. The only water which is really pure is distilled water. But even if it were desirable to use only distilled water for drinking, the process of distilling would make it too costly. Distilled water is used as a water supply only

[1] *Compress* (kom pres'): to squeeze together or to force into a smaller space.

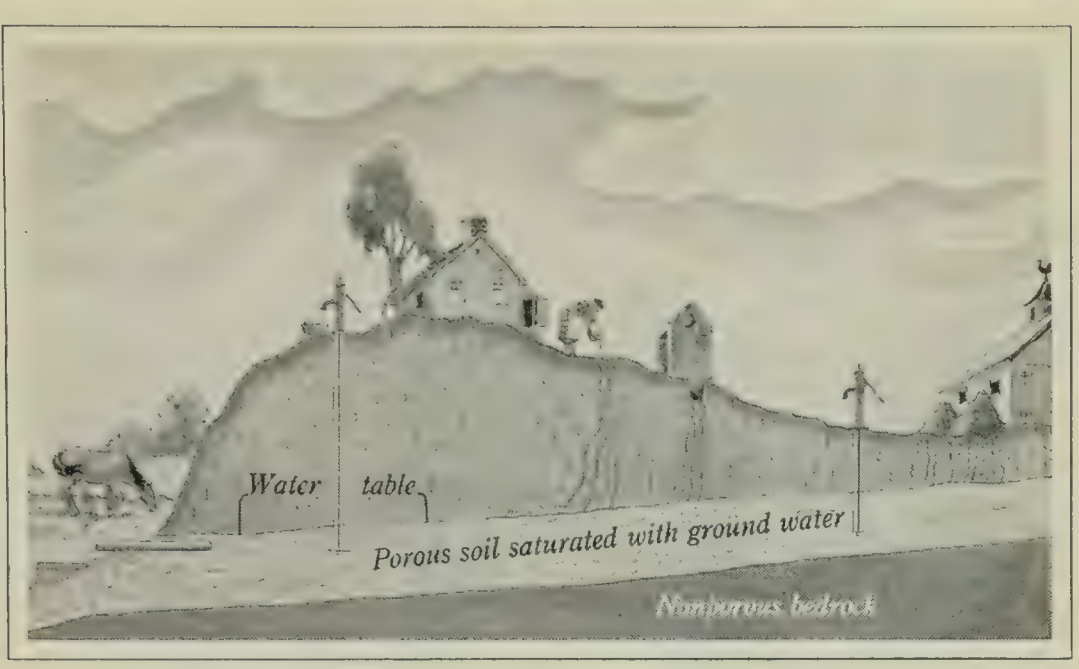


FIG. 55. What are the sources of water pollution in this figure?

on ocean liners, where the cost is of less importance than its convenience. Fortunately we do not need a water supply which is "pure" in the sense that it is entirely free from all substances except water. Drinking water is sufficiently pure if it contains nothing that is unwholesome. Matter which is not alive, such as mud, sand, and dissolved minerals, may give the water an unpleasant color or taste without making it unfit to drink. Living matter, such as bacteria[1] and other living things, however, is always present in natural waters to some extent. These may not impart color, odor, or taste in any way, and yet if certain kinds are present they may render the water entirely unfit for drinking and for household uses. Human and animal excrement[2] is liable to contain the kinds of germs[3] which, if allowed to get into water, make it dangerous to drink. It is necessary, therefore, to make sure that the water supply is not contaminated[4] by animal and human excrement.

[1] *Bacteria* (bak te'ri a): a group of very small plants. Some of the germs which cause diseases are bacteria.

[2] *Excrement* (ex'kre ment): the waste material discharged from the intestines or bowels of animals.

[3] *Germs* (jurms): a name for very small plants and animals which may produce disease.

[4] *Contaminate* (kon tam'i nate): to make dangerously unclean.

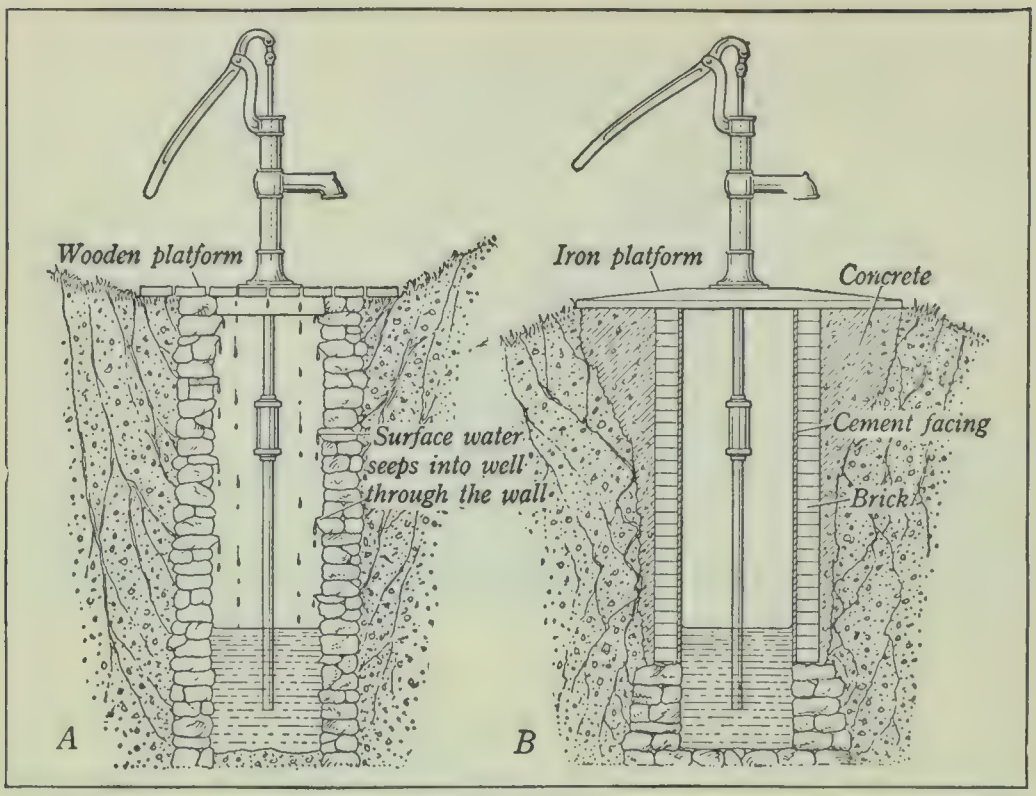


FIG. 56. Wrong and right ways to build a well. In how many ways is the well shown in *B* superior to the one shown in *A*?

***Danger from surface drainage.** People in the country usually depend for their water supply on wells, springs, or streams. But although these sources of water supply may be abundant and conveniently located, there is always grave danger that they may have become polluted[1] by surface drainage (Fig. 55). Even very deep wells, the water of which is usually pure, may become contaminated if they are not so constructed as to prevent surface water from draining into them (Fig. 56). Moreover, it is not always true, as many people believe, that streams become pure by running a few miles, even though the water is exposed to sunlight and oxygen, which kill some disease germs.

*Surface drainage, such as is shown in Fig. 55, may carry to human beings typhoid germs, intestinal[2] diseases, and parasites[3]

[1] *Pollute* (po lute′): to contaminate by adding unclean or dangerous material. *Pollution* (po lu′shun): contamination (kon tam i na′shun).

[2] *Intestinal* (in tes′ti nal): having to do with the intestines (see Glossary).

[3] *Parasite* (pair′a site): a plant or animal which lives in, on, or at the expense of, another living plant or animal.

such as the hookworm and the tapeworm. It may carry to farm animals the germs of hog cholera and anthrax, as well as certain other parasites.

Testing the water supply. In every large city the water is tested daily for purity. In the country, however, frequent tests are impossible. Yet rural people need to find out whether their water supply is pure. To avoid danger they should have the water supply tested to see whether it contains dangerous germs. The state university, the state board of health, or the public-health bureau in the nearest large city will usually make such an analysis, sometimes free of charge. If the source of water is located where it is liable to be contaminated, it should be tested several times during the year.

***Vacation dangers.** While people are on their vacations they sometimes contract typhoid fever and other serious diseases by drinking water which has become polluted with sewage.[1] Visitors to camps or resorts should take great care to make certain that the water supply has been recently tested for purity and has been pronounced wholesome by the state board of health or some other similar agency. In some states the Boy Scouts have done very valuable public service by sending samples of water from streams and wells along the highways to the state boards of health for analysis. They have then put up a sign on each source of water stating whether the board has pronounced the water safe to drink. If the source of water is an open well, a spring, or a stream, however, one cannot always be sure that the water is safe even though it bears a "safe" sign, for the water may have become contaminated since the analysis was made. Boards of health sometimes recommend that people on outing trips make sure that their drinking water is safe by boiling it for twenty minutes or by putting into it a small amount of chloride of lime. The germs in a glass of drinking water may be killed by adding a single drop of tincture of iodine.

***Methods of purifying the water supply.** After the water is brought to the city it must usually be treated to make certain that it is wholesome. Water obtained from rivers and lakes, es-

[1] *Sewage* (su'aj): the waste matter which flows from homes and streets through pipes called *sewers* (su'ers).

FIG. 57. Aerating a part of New York City's water supply. Can you think of any other ways in which water might be exposed to oxygen?

pecially, is liable to be more or less contaminated by surface drainage. Many cities use one or more of the following methods of purifying their water supply: (1) aerating the water, that is, spraying it into the air to kill the harmful bacteria by exposing them to sunlight and oxygen (Fig. 57); (2) filtering it to remove the solid impurities; (3) storing it in reservoirs until the solid impurities settle; or (4) adding a germicide.[1]

Purifying water by filtration. ***Experiment 15.*** Can solid impurities be removed from water by filtering it through sand? Place a one-hole rubber stopper in the end of a long glass tube at least an inch in diameter (Fig. 58). Fill the tube with clean moist sand. Pour water which is slightly muddy into the top of the tube until it begins to drip into the glass. Is the water clearer than before it passed through the sand? Answer with a complete sentence the question asked at the beginning of this experiment.

[1] *Germicide* (jur'mi side): a substance, usually a liquid, which kills germs. While scientists recognize slight differences in the meanings of the words *germicide*, *disinfectant* (dis in fek'tant), and *antiseptic* (an ti sep'tik), these words will be used in this book as having similar meanings.

Experiment 15 illustrates filtration, or the method of filtering water through sand and gravel to free it from solid impurities such as sediment[1] and germs. Filtration is used in many cities (Fig. 59). Practically all the germs can be removed in this way, providing the filtering beds are deep enough and are properly and frequently cleaned.

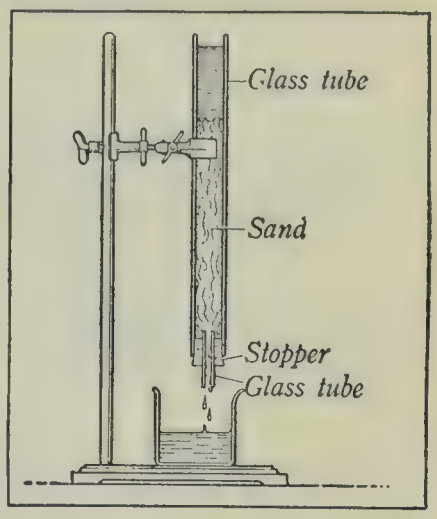


FIG. 58. Exercise on Scientific Method (Using Controls): How does some of the unfiltered water serve as a control?

Are household filters of value? Various types of household filters are intended to remove germs from drinking water. One type consists of a small strainer which screws over the end of the faucet; another consists of a metal tube surrounding porous stone, brick, or other porous materials. It is probable, however, that none of these filters entirely frees the water from germs, even though the filters are frequently cleaned, for many kinds of germs are small enough to pass through the pores of the filter with the water. Moreover, if such filters are not frequently cleaned, the water that has passed through may be found to contain even more germs than the water directly from the faucet, because harmful germs may multiply in the solid material which collects in the pores of the filter. It is not certain that any faucet filter yet invented makes polluted water sufficiently pure for drinking.

Purifying water by storage. The storage[2] method of freeing water from solid impurities consists of allowing the water to remain for several weeks or months in great settling basins, or reservoirs. The solid particles settle very slowly; but if a small quantity of alum is added to the water, a sticky substance is formed to which the solid particles cling. The larger particles thus formed settle more rapidly. These reservoirs must be cleaned regularly.

[1] *Sediment* (sed'i ment): solid or undissolved particles in water or other liquid.

[2] *Storage* (stor'aj): the act of storing something or the space in which something is stored.

Purifying water with germicides. When water is purified chemically (that is, by adding a germicide) the germs are not

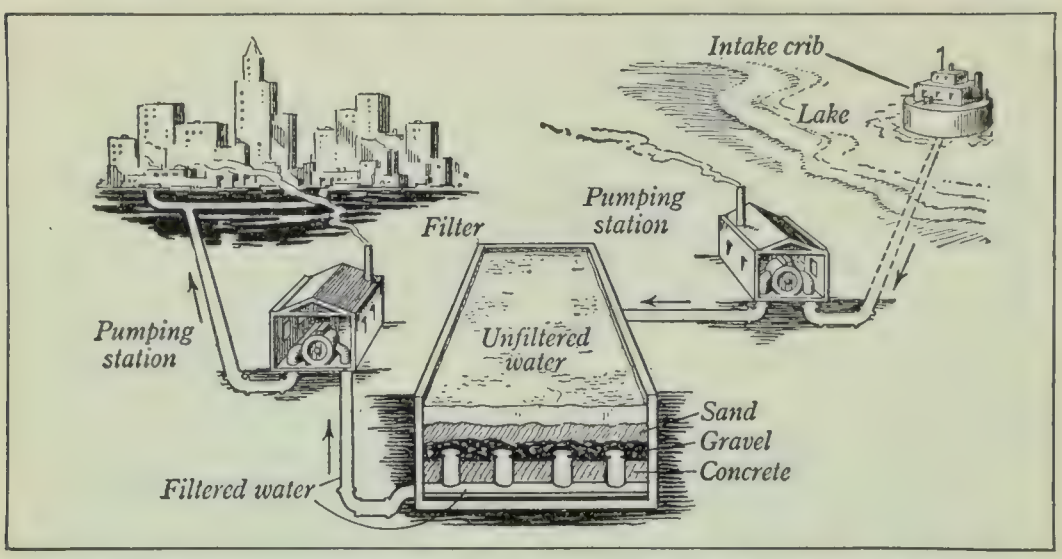


FIG. 59. Can you trace the course of the water from the intake crib to the city?

removed but are killed. Usually liquid chlorine is added to the water in very small quantities, which are sufficient to kill the germs but not to injure human beings. Millions of gallons of water are thus purified daily in city water systems.

Does pure water contain germs? There are always some bacteria in the water supply. There are two reasons why it is not necessary that drinking water should be entirely free from bacteria: (1) the body is able to overcome germs when these are not too numerous; and (2) not many kinds of germs are harmful. Whenever the daily tests show a marked increase in the number of germs in the water or show germs of a dangerous nature, the health authorities at once take steps to restore the water to the necessary degree of purity.

Self-test on Problem V–C. (*Do not write in the book.*) 1. Water may be *wholesome* to drink in spite of dissolved minerals which it may contain.

2. Water is dangerous to drink when it has become contaminated with disease __(?)__ from human and animal wastes.

3. Water from deep wells is *more likely* to be contaminated than surface water.

4. A dangerous disease known to be contracted sometimes from drinking water is (1) hydrophobia; (2) rheumatism; (3) paralysis; (4) cancer; (5) typhoid fever.

5. Water which has a "safe to drink" sign from the board of health is *always* safe to drink.

6. Harmful germs in water are *removed* by oxygen and sunlight.

7. Filtering water through sand and gravel removes (1) none; (2) a few; (3) many; (4) nearly all; (5) all the harmful germs.

8. Water may be made safe for drinking by adding to it a small amount of (1) salt; (2) chloride of lime; (3) plaster of Paris; (4) carbon dioxide; (5) soda.

Self-test on Scientific Principles. 1. Can you find in this chapter examples of the principle "Water tends to seek its level"? This statement means that water always tends to flow, or to become adjusted, so that its surface is everywhere at the same level.

2. What illustrations can you give of this principle: "The pressure at any point below the surface of water becomes greater as the depth of the water increases."

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What are the advantages and the disadvantages of the three locations of the water tank: outside the house, on the roof, or in the attic?

2. The pressure in the faucets becomes less the higher they are in the building. Explain.

3. Can you draw a diagram which shows why wells sometimes go dry during the summer?

4. In a town or a city the water pressure in the faucets, in summer especially, is often less in the later afternoon and early evening than in the morning. Explain.

Special Reports. 1. How does a hydraulic ram lift water from a running stream into a reservoir above the stream?

2. Describe the advantages and the disadvantages of the source of the water supply in your home or in the town or city in which you live. How is it kept pure or made pure?

3. Find out to what extent water meters are used in your town.

Books for Reference

GARNETT, WILLIAM. A Little Book of Water Supply. The Macmillan Company, New York.

MEISTER, MORRIS. Water and Air. Charles Scribner's Sons, New York.

Chapter VI · Keeping Clean with Water

Questions this Chapter Answers

How are soaps made?
How do soaps aid in cleansing?
What is soft water? hard water?
How is hard water made soft?
How do machines aid in keeping clean?
How are stains removed?
How are the problems of sewage disposal solved in the country and in the city?
What constitutes good plumbing?

Problem VI–A · How is Water Used in Keeping Clean?

Water and soap. How difficult it would be to keep clean without water! Imagine the condition of our bodies, our homes, and our cities without water and the knowledge of how to use it to keep ourselves and our environment clean and sanitary.[1] Such knowledge, however, has only recently been gained and is by no means general in all parts of the world.

Pliny[2] states that soap was invented by the Gauls. His writings do not say that they used it for washing or cleaning but only to give a bright color to the hair. It was probably introduced by the Germans into Rome, where it was used both as a medicine and as a cleansing agent. It was first made from goat's tallow and the ashes of beechwood.

Soft soap and hard soap. Every pioneer family had either to make its own soap or to go without. The lye (potassium carbonate in water) which they used for soap-making was obtained from hardwood ashes. The ashes were either boiled or leached to dissolve the lye from them. In leaching, the ashes were put into a barrel or into a hollow log or trough, and were then soaked with water. The water as it slowly filtered through the ashes dissolved the lye from them, then dripped into a wooden pail or trough.

[1] *Sanitary* (san'i ta ry): having to do with healthful conditions.

[2] *Pliny* (Plin'y): a Roman scientist and writer (23 A.D.[3]–79 A.D.).

[3] *A.D.*: the first letters of "Anno Domini," which means "in the year of our Lord," or since the birth of Christ.

FIG. 60. Making soap in pioneer days. Can you think of any kinds of fats or oils used in soap-making today which were unknown in colonial times?

This lye was then strained and boiled with lard or tallow (Fig. 60). The resulting product was soft soap. This soap could not be made into bars.

*Hard soaps are made today by boiling animal fats or vegetable oils with a lye (sodium hydroxide). Salt is added at the proper time in the boiling, causing the soap to rise to the top. The soap thus separates from the other substances which are produced in the kettle at the same time. The soap may then be poured into pans to harden or pressed into molds as desired. Perfume and coloring matter are added to toilet soaps before they are molded.

***Washing and rinsing.** The skin of the human body is usually moist and oily. Fine particles of dirt may stick to the skin. Some of this dirt, along with dirt from other sources, may be absorbed by our clothing. Water dissolves some solid particles and carries away dirt which is loosened from the clothes and body by rubbing, but water alone will not remove the oily materials (Fig. 61). When soap is added to the water, the oil is broken up into very fine particles which can be removed by rinsing.[1]

[1] *Rinse:* to wash lightly without rubbing.

Keystone View

FIG. 61. French women washing clothes in a brook. State the advantages and the disadvantages of this method of laundering

***Hard water and soft water.** Rain water is the purest natural water because it contains little or no dissolved mineral matter. Mountain water from melting snow is likewise nearly free from dissolved minerals. Mountain water which is not from melting snow usually contains considerable amounts of dissolved materials. The water in lakes, rivers, and wells usually contains minerals which have dissolved into the water as it passed over and through rocks and soil. When water contains any of the compounds of the metals calcium and magnesium, it is called hard water. Water without these compounds in solution is called soft water.

Soap dissolves and readily forms bubbles or suds in soft water. When soap is put into hard water, it combines with the calcium and magnesium compounds and forms a coating on the surface of the water. No soap bubbles will form until soap has

first combined with all the calcium and magnesium compounds in the water. This is the reason why hard water is not satisfactory for laundry purposes, though it is wholesome for drinking.

Some kinds of hard water when heated leave a white solid, which is chiefly lime, on the bottom and sides of the vessel. The heating coils in water heaters and furnaces sometimes become so filled with lime that they no longer heat the water effectively[1] (Fig. 62).

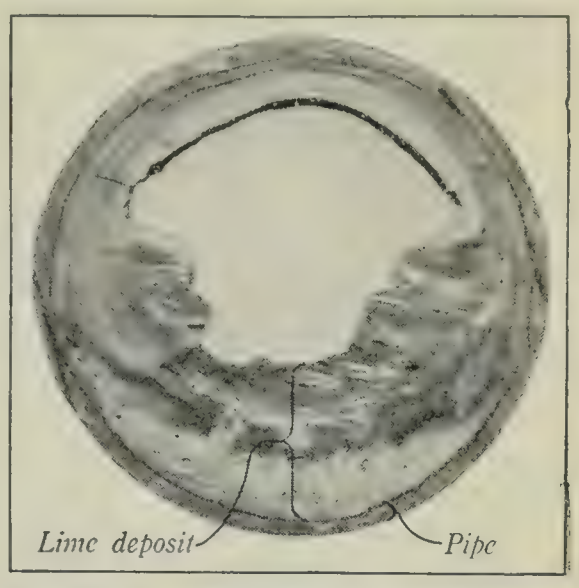


FIG. 62. Cross section of a pipe showing lime deposit from hard water. Should you infer that this was a warm-water pipe or a cold-water pipe? Explain

***Softening hard water.** Rain water is sometimes used for washing and cleaning. Some kinds of hard water can be made soft by boiling. Other kinds of hard water can be made soft only by adding various substances to them. These combine with the calcium and magnesium compounds and remove them from the water, thus leaving the soap free to attack the oils and dirt. Borax and ammonia are especially good for laundering[2] and for softening bath water, but they are expensive for general laundry uses. Washing soda, which is cheaper, is excellent for softening hard water.

*Many washing powders which contain borax and washing soda are useful in softening water. Some of these, however, will injure clothing, especially woolens, if the powders are put directly upon the clothing without first being dissolved in water. Therefore it is safer to dissolve the powder in the water before putting the clothes into the tub.

The coating which soap makes with hard water can be removed from the bathtub by using a cloth upon which a little turpentine or kerosene has been poured.

[1] *Effective* (ef fek'tiv): securing the results expected or desired.

[2] *Launder* (lawn'der): to wash and iron clothes.

Experiment 16. Is the water in the schoolroom hard? If so, can the hardness be removed? Fill one test tube half full of water that is known to be soft, and another test tube half full of water from the faucet. Add small and as nearly as possible equal amounts of soap flakes to each. Shake each test tube vigorously, keeping your thumb over the end meanwhile, and watch for suds or lather in each test tube. If you do not succeed in getting a soap lather in either test tube, keep adding a little more soap flakes to each tube, shaking the tube after each addition of soap, until you do succeed in getting a lather in one of the test tubes. Be sure to add to each test tube amounts of soap flakes as nearly equal as possible. In which sample of water do you first succeed in getting a lather? If the faucet water proves to be hard — that is, if it requires more soap to make a lather than the soft water does — add more soap flakes until you do succeed in getting a lather in the faucet water.

Take two fresh samples of water from the faucet; boil one of these samples in a test tube and let it cool. Add equal amounts of soap flakes to each, shaking vigorously meanwhile, until you succeed in getting a lather in each. Did the boiling make the water softer; that is, did the boiled water require less soap than the unboiled faucet water? Can your faucet water be made softer by boiling it?

Take equal quantities of water from the faucet in four test tubes. To one sample add a little borax, to another a little washing powder, and to the third a little washing soda. Shake the samples so that as much as possible of the solids in them will dissolve, but stop shaking the tubes before all the powders are dissolved in the water. Add small but equal amounts of soap to each of the four samples. Shake each vigorously. In which does the soap form suds first? Continue to add small but equal amounts of soap powder to the remaining samples in which suds have not yet appeared until you get suds in one of them. Which of the three substances — the washing soda, the washing powder, or the borax — proved to be the best softener? Write a complete statement which answers each of the questions asked at the beginning of this experiment. Give a reason for your answer in each case.

Exercise on scientific method (isolating the experimental factor and using controls). Hardness and softness were the experimental factor (see footnote, p. 31) in this experiment. Explain. Controls were introduced in every part of this experiment. What was the control in each part? Why were they necessary?

A device for softening water. In some cities (for example, Columbus, Ohio) where the supply is of very hard water, the water is softened before it is sent into the pipes. Where this practice is not followed, the hard water can be satisfactorily softened

for all household purposes by the use of water-softeners. One type is shown in Fig. 63. The hard water from the supply pipe is admitted at the bottom of the softener. It rises first through fine gravel and coarse sand, and then through a softening compound of sodium, silicon, aluminum, and oxygen. Calcium and magnesium compounds in the hard water combine with the substances in this layer. The softened water then passes out at the top of the tank to the various parts of the house.

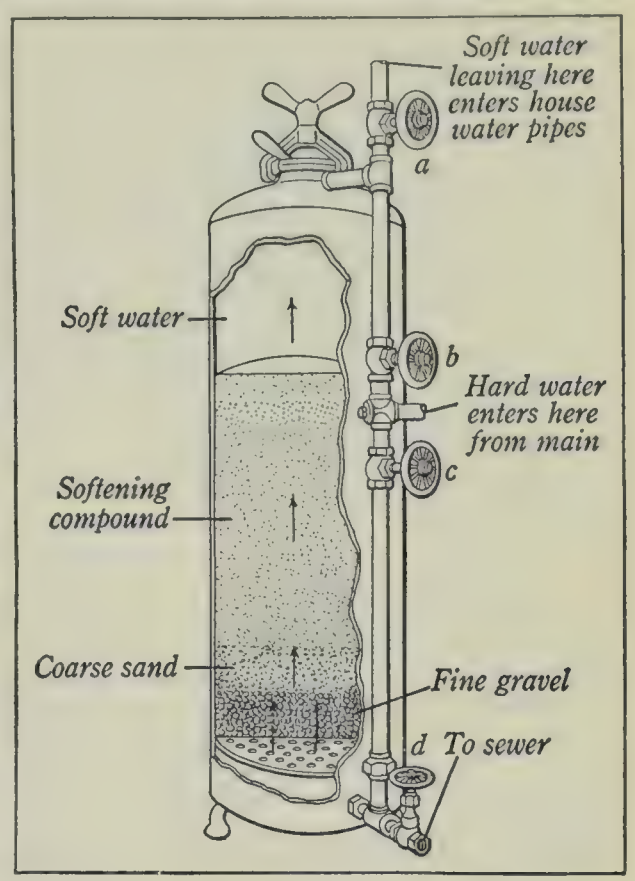


FIG. 63. A water-softener. The tank is cut away so as to show the construction. Valves *a* and *c* are open while valves *b* and *d* are closed. Hard water then enters at the bottom and is so treated that soft water flows out at the top. Can you explain which valves are open and which are closed when the softener is being flushed?

After two or three weeks of use, depending on how hard the water is and how much of it is used, the deposits of calcium and magnesium have to be removed from the softening compound. A strong salt solution is poured into the top of the softener. The salt combines with the calcium and the magnesium compounds and makes the softening compound as it was at first. The softener is then flushed by running fresh water through it and into the sewer.

*__Machines in the home laundry.__ In early times dirt in the clothes was usually loosened by rubbing the wet clothes upon a board or upon a large stone. The washboard is still much used in washing. Washing machines of many types, however, are often used to launder the clothes, and do the work more quickly and quite as well. Fig. 64 shows one type of electric washer. Soiled

clothes are put into the tub with water and soap. A small electric motor, by one or another of several different methods depending upon the type of washer, causes the water to pass rapidly through and about the clothes, removing the dirt. Some types of washer do not have a wringer, but accomplish the same purpose by whirling the clean wet clothes in a cylinder, thus throwing the water out of the clothes into the tub as they whirl.

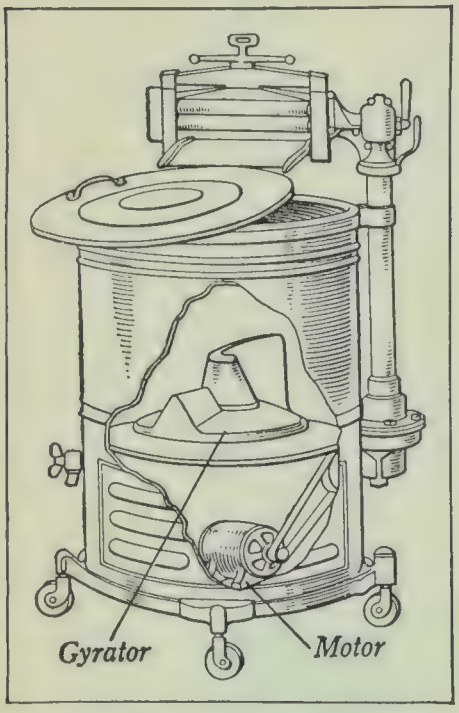


FIG. 64. Diagram of an electric washing machine. Can you describe the way in which this machine operates?

Mangles, or ironing machines, are also used in many modern homes. With these machines the clothes are pressed between metal rolls that are heated either by gas or by electricity. An electric motor turns the rolls.

Removing stains from clothing. People are judged in part by their personal appearance. This statement does not mean that it is necessary to wear expensive clothes or to have several different suits or dresses. It means that one's clothing should be neat, that is, free from holes, carefully pressed and brushed, and free from dirt and stains.

*It is not possible to state briefly how to remove all stains from clothing because (1) there are many different kinds of stains and (2) substances which produce stains act in different ways upon different cloth materials and upon the dyes used in the materials.

*Stains should be attacked as soon as possible, since old stains are harder to remove than fresh ones. Never use strong chemicals to remove stains. If the substance is strong enough to remove the stain quickly, it may also be strong enough to make holes in the cloth. Always work on a small area of the cloth at a time. Remove the stain from that area before you go farther, even though you may be working on only a small part of one stain. Always begin at the edge of a stain and work toward the middle.

FIG. 65. A dangerous way (*A*) and a safe way (*B*) of removing stains from clothing. Explain

***Substances that remove stains.** The commonest stains are probably those made by food and oily substances, ink, and paint. Stains on goods that can be washed can usually be removed by using warm water and soap, meanwhile rubbing the spot thoroughly. Such spots on goods that cannot be washed can usually be removed by sponging the spot with carbon tetrachloride while holding a soft folded towel under the spot to absorb the oil and other materials as fast as the carbon tetrachloride removes them. Carbon tetrachloride is better than gasoline or benzine for cleaning clothes in the home, because it will not explode or burn. The fumes of all cleaning substances, however, are more or less poisonous. Therefore such dry cleaning as is done at home should always be done out of doors (Fig. 65).

Indelible ink cannot be thoroughly removed from cloth. Printer's ink and India ink may often be removed by sponging the stained spot with carbon tetrachloride. Stains made by writing ink can often be removed by applying first ammonia and then oxalic acid, repeating if necessary, then by washing all these chemical substances out of the cloth when the spot is removed. In using oxalic acid and ammonia to remove stains it is always well to try the effect of these substances first upon another piece of the same cloth to see whether it injures the cloth or changes its color. This is especially necessary in the case of silk clothing. Do

not use household ammonia, but get 10 per cent ammonium hydroxide solution from your druggist. The oxalic acid solution is a saturated solution made by dissolving in pure water all the oxalic acid crystals that the water will dissolve. Oxalic acid is a poison and should be kept out of the reach of children.

Paint stains may usually be removed by carbon tetrachloride. If the stain is an old one, moisten the spot thoroughly with carbon tetrachloride, then roll the cloth with the stain inside. The carbon tetrachloride is thus prevented from evaporating so quickly and therefore continues to act upon the spot.

Dry cleaning and pressing. In the modern process of dry cleaning, the clothes are thoroughly washed in large washing machines of the same kind as those used in the home. The liquid used in these machines is usually gasoline, benzine, or a similar liquid obtained from gasoline. Such garments as white trousers and white skirts are washed in soap and water instead of in the cleaning liquid. When the clothes have been in the washing machine a sufficient length of time, they are put into a large cylinder. This cylinder whirls rapidly, removing most of the cleaning liquid, in the same way that some types of washing machines dry the clothes. The clothes are then put into a metal chamber, in which the temperature is between 250° and 300° F.[1] Here the high temperature kills all the germs. The clothes are next placed in a drying room, through which pass currents of warm air. After the clothes are dry, spots which have not been removed by the cleaning liquid are removed by hand. The clothes are now ready to be pressed. Women's garments are practically all ironed by hand with electric irons. Men's garments are usually pressed on pressing machines. These are of several types: one presses the trousers, another the shoulders of the coats, another the sleeves, and so on. The part to be pressed is placed upon a pad connected with a vacuum pump. Another pad, heated with steam, is pressed lightly on the garment. The air pressure forces the steam from the upper pad through the garment into the partial vacuum in the second pad. After the clothes are pressed they are hung in a warm room and left until thoroughly dry.

[1] *F* means "temperature on the Fahrenheit (far'ren hite) thermometer." Fahrenheit, a German scientist (1686–1736), invented this thermometer.

Self-test on Problem VI–A. (*Do not write in the book.*) **1.** Hard soaps are made by boiling fats or oils with (1) salt; (2) potassium hydroxide; (3) soda; (4) turpentine; (5) chloride of lime.

2. Rain water is *hard* water.

3. Hard water can sometimes be made soft for washing purposes by adding (1) salt; (2) sodium hydroxide; (3) oil; (4) borax; (5) calcium compounds.

4. Washing powders frequently contain (1) washing soda; (2) salt; (3) magnesium compounds; (4) turpentine; (5) calcium compounds.

5. A cheap substance of value in softening hard water is __(?)__.

6. An excellent substance for use in removing stains is __(?)__.

7. Stains on clothing should *usually* be removed in the open air.

Problem VI–B · How does Water Help in Disposing of Wastes?

***Sewage disposal in the country.** The problem of sewage disposal is of great importance. It is closely connected with the problem of water supply. The country dweller no longer has a good excuse for having an old-fashioned open outside toilet.

***Septic tanks.** Where the country home is supplied with running water, a septic[1] tank offers a satisfactory means of disposing of the sewage in a sanitary way (Fig. 66). The sewage enters the first compartment. Here it is attacked by certain kinds of bacteria. These bacteria feed on the wastes, killing harmful germs and changing the wastes to a liquid form. The liquid overflows from this compartment into a second one, where the purifying process is continued. The liquid is almost clear when it is finally distributed into the soil through drainage pipes from the septic tank. The soil bacteria complete the destruction of any particles of solid material which may remain, rendering the wastes entirely harmless.

Septic tanks are commonly constructed either of concrete or of metal. Metal septic tanks (Fig. 66) can be bought, and need only to be buried in the earth and connected with the drainage pipes.

The septic tank should be connected only with the toilet. It is best if the kitchen sink has a separate drain into a grease trap,

[1] *Septic* (sep'tik): producing decay through the action of certain kinds of bacteria.

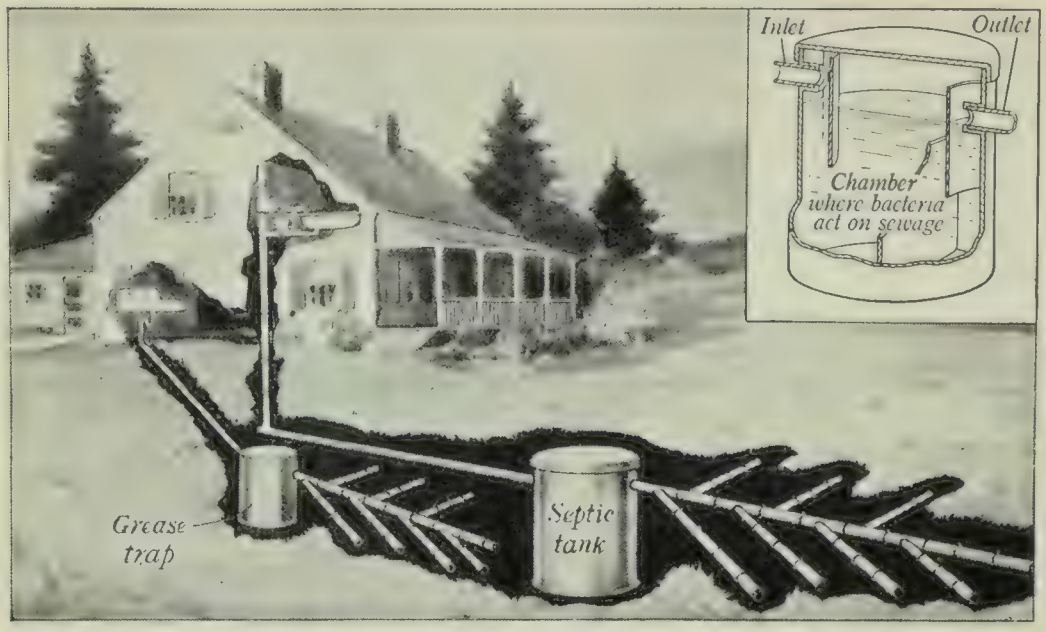


FIG. 66. Sewage disposal in a country home. Why is a septic tank superior to a cesspool?

since grease sometimes clogs some of the pipes of the septic tank and may also interfere with bacteria which make the sewage harmless. Disinfectants, such as lye or strong acids, should never be poured into a toilet which drains into a septic tank, because the disinfectant would kill the germs that purify the sewage.

The cesspool a source of danger. The cesspool is sometimes used for sewage disposal in rural homes. The cesspool is a large and fairly deep hole in the ground into which the sewage from the house empties. Its sides are commonly lined with stone or brick. A thick layer of stones is placed in the bottom to hold the solid materials until the bacteria of decay can change them into harmless liquids. These liquids then sink into the ground beneath. The cesspool may become a source of danger because there is nothing to prevent some of the liquids carrying disease germs from sinking into the ground before the bacteria of decay have had an opportunity to destroy them. The septic tank, if running water is available, can be constructed at little more expense than the cesspool and is safer and more satisfactory.

***Other sanitary ways of disposing of sewage.** The country home which is not supplied with running water can be equipped with an indoor chemical closet at very small cost. The wastes are

received in a large pail partly filled with water containing a small quantity of antiseptic solution. This antiseptic solution kills the germs and prevents unpleasant odors. About every ten days the contents of the pail are emptied into a barrel from which the bottom has been removed and which has been buried in the ground. The wastes, which have been changed almost entirely to liquid form, sink into the ground and do no harm.

*Another sanitary substitute for the old-fashioned open toilet is the dry-earth toilet. An outside toilet is constructed in the ordinary way, except that the vault is made of concrete instead of being merely a hole in the ground. Whenever the toilet is used, the wastes are sprinkled with a small amount of chloride of lime to kill the germs and then are covered with dry dust or sand. Thus the wastes are made harmless[1] and odorless.[1] The vault can be emptied of its dry contents without difficulty.

The chemical toilet and the dry-earth toilet are recommended by boards of health not only for use in country homes but also for churches, country schools and hotels, camps, and pleasure resorts.

***Sewage disposal in cities.** The enormous quantity of sewage from a great city makes its proper disposal a difficult problem. Cities by the ocean commonly pipe their sewage a long distance from shore. The sewage is broken up and made harmless by the motion of the water and by living things in the ocean. Inland cities find the disposal of sewage more difficult. The practice of draining the sewage into a lake or river close by is the cheapest way to dispose of the sewage. This practice does not remove the dangers, especially to cities which take their water supply farther down the river.

*Small inland cities often dispose of their sewage in a sanitary way by means of large septic tanks with many compartments. The sewage empties from the last compartment into a filter bed, from which it drains as a harmless liquid into the soil or into a stream. The solid materials must be removed from such a septic tank at regular intervals. These can be put into separate tanks where the bacteria complete their destruction, or they can be disinfected and removed to a safe place of deposit.

[1] *Less* at the end of a word means "without" or "unable to do." Thus, *harmless* means "unable to do harm" and *odorless* means "without odor."

FIG. 67. The Chicago sanitary and ship canal carries the discharge from sewage-treatment plants and the storm water of Chicago and its suburbs. It is 32 miles long and is 24 feet deep. It serves as the connecting link in the Illinois waterway. What living things do you think were chiefly responsible for making the sewage harmless before it was allowed to enter this canal?

*Some large inland cities drain their sewage into large septic tanks which partly purify it. A disinfectant is then added before the sewage is drained away. In other large cities the solid matter is first separated from the liquid. The solid wastes are then put into very large tanks, where they are made harmless by the action of certain bacteria. The liquid wastes are sprayed into the air, where the sunlight and the oxygen in the air will kill some of the germs. This liquid is then allowed to filter through great beds of broken coke,[1] where bacteria continue the purifying process. It is finally filtered through beds of sand and gravel, which complete the process, before it is drained away (Fig. 67).

Sanitation depends on good plumbing.[2] The plumbing of a house should be so planned and installed that it can easily be examined and repaired at any point. Water pipes may be protected from freezing by wrapping them with felt or asbestos. Outside pipes, such as those into tanks, are sometimes protected

[1] *Coke*: the solid which remains after some of the gases have been removed from soft coal.

[2] *Plumbing* (plum'ing): all the gas, water, and sewer pipes in a building.

from freezing by first wrapping them loosely with newspaper, then covering the newspaper with felt. The large pipes, or water mains, which carry the water from the reservoirs to the homes are buried far enough below the surface of the ground to prevent the water in them from freezing.

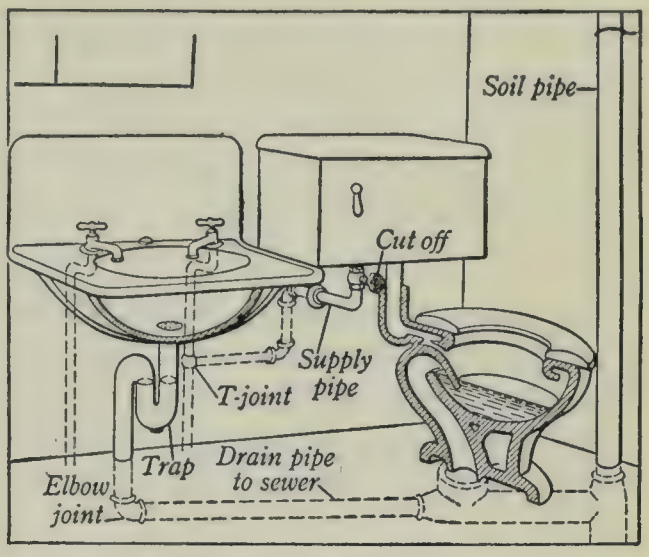


FIG. 68. Locate the cutoffs, traps, elbow joints, and T-joints in this diagram. **Special Report:** Find out how a flushing tank operates. Make a diagram to use in explaining its action

The outlet pipe below the sink, washbowl, wash trays, and bathtub, and in the bottom of the toilet bowl (Fig. 68), is always curved like a siphon. This bend is called a trap. Some water always remains in the trap, thus preventing sewer gas from coming into the house through the drains. All the drains are connected with a pipe called the soil pipe. The upper end of this pipe extends through the roof and thus provides a means of escape for sewer gases. Traps are usually kept clean by flushing them with quantities of water and also by occasionally flushing them with hot water in which a small amount of lye has been dissolved. Most traps are equipped with a screw cap in the bottom of the bend. This cap can be taken out in case the trap becomes closed.

Cutoffs (Fig. 68) make it possible to shut off the water at certain places and to repair plumbing without shutting off the water from all parts of the house. Elbow joints (Fig. 68) are used to save the labor and difficulty of bending pipes when it is desired to carry the plumbing around corners. T-joints (Fig. 68) are used to start a branch from a main pipe.

Self-test on Problem VI–B. (*Do not write in the book.*) **1.** The best method of sewage disposal in country homes which are equipped with running water is (1) the cesspool; (2) the dry-earth toilet; (3) the septic tank; (4) the chemical toilet; (5) the common outdoor toilet.

2. Two satisfactory ways of disposing of sewage in country homes which are not supplied with running water are the _ _(?)_ _ toilet and the _ _(?)_ _ toilet.

3. It is *never* a safe practice for *cities* to empty their sewage directly into lakes or rivers close by.

4. *All* bacteria in sewage are *harmful.*

5. City septic tanks for the disposal of sewage in cities consist of several compartments in order to give more time and opportunity for the _ _(?)_ _ to purify the sewage.

Self-test on Scientific Principles. 1. Can you give examples from this chapter which illustrate this scientific principle: "Living things by their life activities affect the welfare of other living things"?

2. Can you find in Fig. 68, p. 105, two illustrations of the principle "Water tends to seek its level"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is a dry-earth toilet or a chemical toilet a better method of disposing of sewage than a cesspool?

2. In most homes a cutoff is installed just inside the house at the point where water first enters from the main, and another at the point where the water pipe crosses the property line from the street. What is the purpose of these cutoffs?

3. By touching the tongue to a cake of soap one can usually find out by the taste whether the soap contains much more lye than was enough to combine with the fat. Mild-flavored soaps contain less uncombined lye than strongly bitter-flavored ones. Why is a soap hard on the skin and clothing if it is made with more lye than just enough to combine with the fat?

Project. To make soap. Put 10 grams of sodium hydroxide (lye) into a clean, empty can such as a lard can and add 60 cubic centimeters of cold water. When the lye has dissolved in the water, add 25 cubic centimeters of alcohol and 25 grams of lard or vegetable oil or vegetable fat. With the cover almost completely covering the open end of the can, place the can upon a support stand. Bring the mixture in the can *just to* the boiling point and keep it just at the boiling point thirty minutes. Do not allow the mixture to boil. Stir the mixture constantly while it is being heated. [CAUTION: *Do not get your face near the open end of the can, as the lye sometimes spatters. Have at hand some vinegar, and in case any of the lye gets on your skin put vinegar on the spot at once. Be especially careful not to let any of the lye spatter into your eyes. There is little or no danger in*

performing this experiment if you follow instructions carefully.] After thirty minutes stop the heating. Add about 200 cubic centimeters of water (preferably distilled water or clear rain water) and again heat the mixture to the boiling point. Remove the flame, and while the mixture is still warm add 25 to 30 grams of salt, a big pinch at a time. Stir the mixture carefully after each pinch has been added. After all the salt has been added and stirred in, let the mixture cool.

The soap will be in a solid cake on the surface of the liquid in the can. Remove the cake of soap and rinse it with a little water.

Exercise on Scientific Attitudes. Mr. Coe is building a fence round his place. The lot, which slopes steeply, is 50 feet wide and 100 feet deep. Mr. Coe is putting pickets across the front and narrow boards along the sides and the back. He will paint the fence green to match the house. How many feet of fence will he have round his place?

Which of the scientific attitudes (pp. 12 and 13) applies to this problem?

Special Reports. 1. Find out what you can about the composition and values of hard-water soap and of scouring powders.

2. Discuss the advantages and the disadvantages of the method of sewage disposal used in your town or city, or make a survey of your neighborhood to find the number of farm homes where septic tanks, chemical closets, dry-earth toilets, or cesspools are used.

3. How many traps, cut-offs, T-joints, and elbow joints can you locate in your home?

4. How many kinds of materials are used in making pipes for the plumbing of various parts of the house?

5. Protecting iron pipes from rust.

6. The sewage problem in buses, trains, and airplanes, and the dangers of polluting the water supplies of the country by these devices for transportation.

7. The making of liquid soap.

8. The use of a rubber suction cup or force cup to open washbowl pipes that are stopped.

Books for Reference

HARDENBAUGH, W. A. Home Sewage Disposal. J. B. Lippincott Company, Philadelphia.

HAZEN, A. Clean Water and How to Get It. John Wiley & Sons, Inc., New York.

UNIT III · *Knowing and Using Matter, Energy, and Work*

PROBLEMS DISCUSSED IN THIS UNIT

Suppose that in the school yard or in your lawn at home there is a large rock which must be removed. Suppose that you and several of your friends were to try to roll the rock away. Suppose you were to push and tug at the rock until all were too tired to continue, but were not successful in moving the rock at all. Suppose that then a team of horses were hitched to the rock, and were to pull as hard as they could but without success in moving it. Neither you and your friends nor the horses would have done any real work during all these efforts. It is true, of course, that you and they would have been exerting force upon matter. Also you and they would have used up considerable energy in the attempts to move the rock.

Suppose again that you were given an unusually long lesson to learn. Suppose you were to sit quietly studying it for several hours. You might even become exhausted from study, and yet would not have done any work in the scientific meaning of work, although you would have used up much energy.

If trying very hard to move a rock, though without success, is not work, and if studying for a long time is not, what is work? In this unit we shall learn what scientists mean by work. Also we shall learn how matter, energy, and work are related to one another. The problems of this unit are these:

What is the nature of matter?
What are some important properties of matter?
What are the nature and the importance of energy?
What are some factors involved in doing work?
Of what importance to progress are machines?
What are the relations between work and efficiency; between work and power?

Chapter VII · The Importance of Matter

Questions this Chapter Answers

What is matter?
In what states is matter found?
What are acids, bases, and salts?
What are elements, compounds, and mixtures?
What are the characteristics of molecules?
What are physical and chemical changes?
What is meant by analysis and by synthesis?
Can matter be created or destroyed?
What are the nature and the advantages of the metric system?
What are inertia, centrifugal force, gravity, density, specific gravity, cohesion, and adhesion?

Problem VII-A · What is the Nature of Matter?

***What is matter?** Everywhere in our environment there are found many different kinds of substances, or matter. We see and use these various kinds of matter, such as water, wood, cloth, and the like, so constantly that we take most of them for granted and give attention only to the unusual ones or to those which happen to be particularly important to us. Matter is the general name given to all substances of every sort. Matter is anything that occupies space and has weight.

Experiment 17. Is air matter? Thrust a drinking glass mouth downward into a pan or dish of water. Does the water enter the glass? Can you account for what you observe? Why do you think the air is or is not matter? If you have trained yourself to observe carefully, you can answer the following question and be certain that your answer is right: How far did the water enter the glass? Not at all? About halfway up? Just a little? Clear to the top? Nearly to the top? Repeat the experiment to make sure whether your answer is right.

Experiment 18. Is air matter? Weigh a basketball carefully before you inflate it. Inflate it and again weigh it carefully. Is the weight the same in both cases? Can you account for what happens? Why do you think that air is or is not matter?

Organic and inorganic matter. All matter can be divided into two classes: organic matter and inorganic matter. Organic matter

FIG. 69. Bears in Yosemite National Park, California. What matter is organic and what is inorganic in this picture? What objects in this picture are organisms (see Glossary)?

includes all living things and their products and usually whatever was once part of a living thing. Thus, yourself, an orange, a cow's horn, an egg, a dandelion, a dog, salad oil, and your hand are all organic matter. All organic matter is made up of carbon, oxygen, and hydrogen, often together with some other substances. Chemists have learned to make many organic substances in the laboratory. Inorganic matter includes everything that is not organic. Inorganic matter is not alive and never was alive. Oxygen, soil, water, rock, and silver are all examples of inorganic matter (Fig. 69).

*States of matter. Perhaps you have never seen melted gold or silver. These metals are rarely seen in any state except the solid state, as in jewelry, silverware, and the like. Perhaps you have seen other substances, such as lead, both in the solid state and in the liquid, or melted, state. Perhaps you have never seen mercury in any but the liquid state, though if cooled sufficiently it becomes a solid which looks much like lead. Still other sub-

Ewing Galloway

FIG. 70. An iceberg near Greenland. Water can be seen here in two of its three states. In what state is water invisible?

MACLEAN SCHOOL

stances are probably familiar to you in all three states. For example, you are doubtless familiar with solid cakes of paraffin, with the melted or liquid paraffin which is poured upon the top of jelly in glasses, and with the gaseous[1] paraffin which vaporizes[2] and burns in a candle flame. Thus matter exists in three states: as a solid, a liquid, and a gas. At low temperatures most substances are solids, at higher temperatures they become liquids, and at still higher temperatures they become gases (Fig. 70).

***Acids, bases, and salts.** You are familiar with the sour taste of lemon juice and of vinegar. These substances are acids. Acids have a sour taste[3] and cause blue litmus paper to turn red. Lye and ammonia are bases. Bases are never sour, and they cause red litmus paper to turn blue. When a base and an acid are put together, water and a salt are usually formed. For example, when hydrochloric acid and common lye are put together, water and common table salt result. Salts have no effect on litmus paper. We shall have occasion to refer to acids, bases, and salts in the pages that follow.

[1] *Gaseous* (gas'e us), *vaporous* (va'per us): like a gas or vapor.

[2] *Vaporize* (va'per ize): to change to a vapor.

[3] Many acids and bases are so strong that it is not safe to taste them.

Experiment 19. Which of a number of common substances are acids? Which are bases? Which are salts? Test with strips of red and blue litmus paper a number of common substances, such as fruit juices, limewater, and table salt. Make a list of the substances, stating which you find to be acids, which bases, and which salts.

Unscientific beliefs concerning the composition of matter. Thales,[1] an early Greek philosopher, believed that there was one substance which was a part of every other substance. That substance or element, he thought, was water. Later Greek philosophers thought that there was not just one but that there were four simple substances or elements, namely, earth, water, air, and fire. They believed that all substances in the world were made up of just these four elements, combined in different proportions. Even today "wise men of Tibet" (philosophers) believe that there are only five elements, earth, air, fire, water, and "ethereal space," which together make up all things.

***Scientific facts concerning the composition of matter.** Modern science has proved that there are ninety-two elements. An element is a simple substance that cannot be broken up into anything simpler. Thus, oxygen, gold, iron, carbon, and mercury are elements. Any sample of any of these that you might find would be composed of that one substance alone. Every kind of matter is composed of one or more of these ninety-two elements.

***Molecules, atoms, and electrons.** Elements, like all kinds of matter, are made up of minute particles called molecules. Each molecule is made up of one or more still smaller particles called atoms. The molecules of any element consist always of the same kind of atoms. Thus every molecule of mercury has one atom of mercury; every molecule of oxygen has two atoms of oxygen (Fig. 71, *A*). Later we shall need to know that atoms are composed of still smaller units called electrons and protons.

***Compounds.** The atoms of different elements combine to form compounds. Sometimes energy is necessary to cause elements to combine. Sometimes energy is given off when a compound is formed, as when, in burning, carbon gives off heat energy as it com-

[1] *Thales* (thay'leez): philosopher, astronomer, and geometer; one of the "seven wise men of Greece" (640 B.C.–546 B.C.).

bines with oxygen to form carbon dioxide. A molecule of a compound always contains more than one kind of atom (Fig. 71, *B*). Thus, the carbon dioxide molecule has atoms of oxygen and carbon.

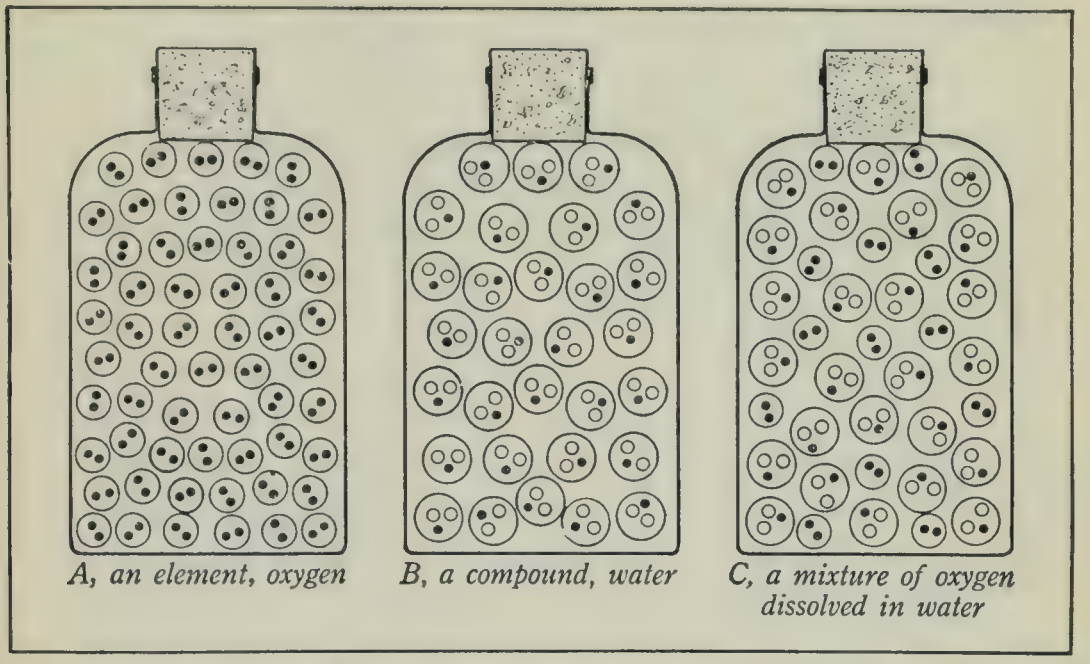


FIG. 71. The dots and the smaller circles inside the larger circles represent atoms in molecules. The small circles inside the water molecules (*B*) represent hydrogen atoms; the dots, oxygen atoms. Can you explain these diagrams?

Not all compounds are formed directly from elements. Sometimes elements combine with compounds to form other compounds. Also, sometimes compounds combine with compounds to form still other compounds. Thus the molecules of a compound formed from two elements may have as few as two atoms, while one formed from other compounds may contain hundreds of atoms.

*Mixtures. Elements and compounds may exist together without forming new compounds. In such cases they are a mixture (Fig. 71, *C*). Air is a familiar mixture. Every sample of air contains chiefly molecules of the elements oxygen, nitrogen, and argon, together with molecules of the compounds water and carbon dioxide. Ocean water is a mixture chiefly of water molecules and salt molecules. Unlike an element and a compound, a mixture is not necessarily always the same in every part. Thus one sample of air may contain more carbon dioxide, water vapor, or dust than another; the lemonade in the top of a glass may taste too sour because it has fewer sugar molecules than that near the bottom.

Other characteristics of molecules. It is not correct to say that matter contains molecules, because all matter is composed entirely of molecules. Molecules are always in rapid motion, though their speeds may vary. The fastest-moving molecules are those of hydrogen. These molecules are believed to travel at a rate of more than a mile per second. Molecules are much too small to be seen with the eye. It would take many thousands of them together to make a speck large enough to be seen with the strongest microscope. Yet scientists have determined their size, their weight, and the speed with which they move.

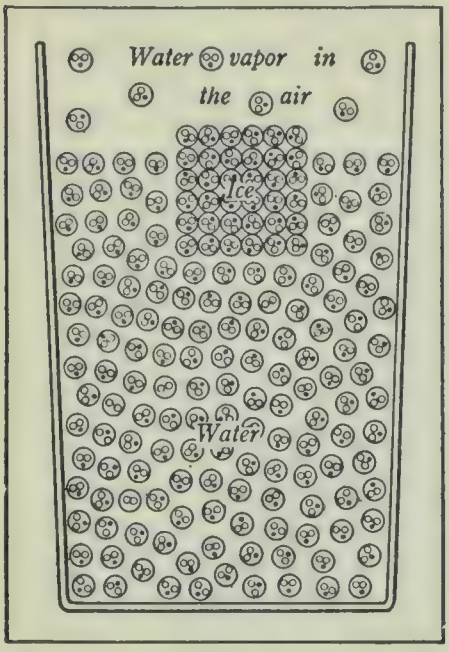


FIG. 72. The larger circles represent molecules of water. Can you explain this diagram?

When matter is in the solid state the molecules are thought to be packed closely together. In the liquid state they are thought to be farther apart, and to move about, over, between, and round each other easily. In the vaporous, or gaseous, state they are very great distances apart in comparison with their size (Fig. 72). A noted scientist has computed[1] that if the molecules in a cubic inch of air could suddenly be made as large as fine grains of sand, they would fill a trench three feet deep and a mile wide extending from San Francisco to New York.

All the molecules of the same kind of matter are alike. Thus molecules of water are like one another,[2] and every molecule of pure iron is exactly like every other molecule of pure iron. But molecules of water are not like molecules of iron. In fact, molecules of one kind of matter are never exactly like the molecules of any other kind. For this reason different kinds of matter have

[1] *Compute* (kom pute'): to reckon; to work out with figures, as a problem.

[2] Recently so-called "heavy water" has been discovered, by which is meant that in a very small percentage of water molecules the hydrogen atoms have a double allowance of electrons and protons and so are different from ordinary hydrogen atoms.

FIG. 73. What physical and what chemical changes are illustrated in this figure?

different characteristics or special properties. Thus different kinds of substances have different colors, sizes, and shapes. Some are hard, others soft; some are heavy, others light; some are more easily bent or twisted; some are more easily pressed or hammered out of shape; some are better for certain purposes than other kinds of matter, usually because the molecules composing the different substances are different. The molecules composing samples of the same kind of matter in different states are exactly the same. Thus the molecules of water, ice, and water vapor (Fig. 72) are alike. Yet the properties of the samples are different, because the molecules are arranged differently in the different states of the same kind of matter. Pure coal and diamonds are made up of the same kind of molecules but arranged differently; that is, they both consist of carbon and of nothing else.

Physical and chemical changes. Energy in one form or another is constantly producing changes in our environment. When matter changes only in state or in form, the change is said to be a physical change. In a physical change the molecules remain the same. No new substance is formed. Thus the tearing of paper and the removing of the skin from a potato are physical changes because the paper is still paper and the raw potato is still raw potato. But when matter is changed to a substance different from what it was, the change is said to be a chemical change. In a chemical change the molecules are changed because the numbers and kinds of atoms in the molecules are changed. Thus the burning of paper and the cooking of potatoes are chemical changes because burned paper and cooked potatoes are entirely different substances from unburned paper and raw potatoes (Fig. 73).

Water, or hydrogen oxide, may be in liquid form, as usually seen; it may be frozen into snow, sleet, or ice; or it may be heated until it becomes water vapor, or steam. The change from ice to liquid or to water vapor is merely a change in state, and hence is a physical change produced by a change in temperature. It is not a chemical change, since water as a solid, a liquid, or a gas is still hydrogen oxide; that is, water molecules, whether they are in the state of ice, water, or water vapor, are each composed of three atoms, two of hydrogen and one of oxygen (Fig. 72). But when water is changed into hydrogen and oxygen by an electric current, a chemical change has occurred. The hydrogen oxide (water) molecules no longer exist; in place of any two of them we have three molecules of gas, two of hydrogen and one of oxygen.

Experiment 20. Can we produce both physical and chemical changes with iron and sulfur? Crush into a fine powder a small lump of the element sulfur. Have you produced a physical change in the sulfur or a chemical change? Add to the sulfur about half as much fine iron filings as the amount of sulfur. Mix the iron and sulfur thoroughly. Hold a magnet[1] near enough to the mixture to attract the iron filings. Does removing the iron with the magnet produce a physical change in

[1] *Magnet* (mag'net): a piece of iron, steel, or other metal which attracts iron or steel. It possesses *magnetism* (mag'ne tizm) and is *magnetic* (magnet'ik).

the mixture or a chemical change? Again mix the iron and sulfur. Heat the mixture in a test tube (Fig. 74). When the contents of the tube begin to glow brightly, remove the burner and allow the contents to cool. Break the test tube and examine its contents. Some of the sulfur may continue to burn. Do not inhale the fumes; they are unpleasant, though not very dangerous. Can you see anything now which looks like either the iron or the sulfur? Does the magnet now attract any of the material? Have the iron and the sulfur been changed? Did the heat energy from the burner produce a physical or a chemical change in the mixture of iron and sulfur?

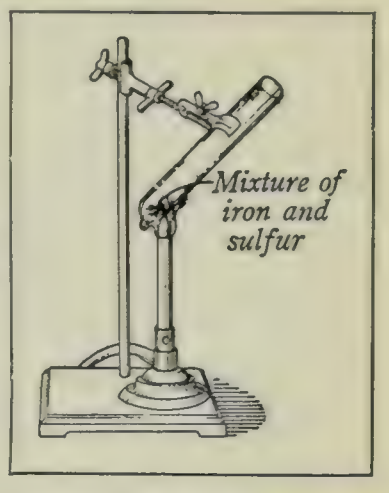


FIG. 74. What kinds of change occur when the sulfur melts? when it burns?

*Solutions. If a pint each of the grains of wheat and corn are poured together and thoroughly stirred, a mixture of wheat and corn results. The structure of the individual grains will not have been changed, and all can be separated again. Similarly, if vinegar is added to water, the two liquids mix very readily. The vinegar molecules become scattered among the water molecules, just as grains of wheat become scattered among grains of corn. Also, when solids such as sugar or salt are dissolved in water, the molecules of the solid mix throughout with the molecules of the liquid. The mixtures of vinegar in water and of salt or sugar in water are solutions, and represent physical changes because the molecules have not been changed. Often, however, chemical changes occur readily between certain substances in solution when these same substances not in solution would combine slowly or not at all.

Analysis and synthesis. When a substance is studied to find the chemical elements or compounds of which it is made, the substance is said to be analyzed, and the process is called analysis. Thus, a chemist may analyze a sample of oil or gasoline, a sample of rock containing gold, or a sample of food. Skillful chemists can analyze most substances and determine what elements or compounds compose them. In the process of chemical analysis the sample is broken up by chemical changes. The opposite process

from analysis is synthesis. In synthesis a compound is built up by combining elements and simpler compounds through chemical changes. Chemists are now able to synthesize a great number of important compounds. Thus synthetic gasoline is built up from carbon, hydrogen, and oxygen, but refined gasoline is produced directly by distilling petroleum.

Can matter be created or destroyed? Matter can be made to undergo changes which sometimes make it seem as if it had been destroyed and new substances created. Thus, (1) it can be changed from one state to another; (2) it can be changed in form and appearance; (3) it can combine with other kinds of matter to form still different substances. But matter can never be destroyed in the sense that it no longer exists, nor can new matter be made out of nothing and added to the matter that already exists. For example, you have seen displays of fireworks at a Fourth of July, Christmas, or other celebration. You have afterward, perhaps, examined the burned-out tube of a skyrocket, a pinwheel, or a Roman candle. The tube appeared to be empty, for the solid matter, the gunpowder which had occupied the hollow of the tube, had been removed and air had taken its place. At the time that the fireworks were "going off," chemical changes were taking place. The solid powder was being transformed (changed) mostly into gaseous compounds. These became scattered about in the air. All the matter which had occupied the tubes still existed somewhere, however, even though you could no longer locate or recognize it.

The metric system for measuring matter. From earliest times it has been necessary to have some method of weighing and measuring matter. Thus practically everything we eat, wear, or use is weighed or measured in some way before it comes to us. Almost all the civilized world except the United States, Canada, England, and Russia uses the metric system of weights and measures. It is much more convenient than other systems. The metric system is like our money system in that each unit or measure is one tenth the size of the next larger unit or measure. Thus with our money ten cents make a dime, and ten dimes make a dollar. In the metric system, likewise, each unit is ten times the next smaller unit, as is shown in the following tables:

Measures of Length

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 meter (m.)
1000 meters = 1 kilometer (km.) = 0.62 mile

Measures of Weight

10 milligrams (mg.) = 1 centigram (cg.)
10 centigrams = 1 decigram (dg.)
10 decigrams = 1 gram (g.)
1000 grams = 1 kilogram (kg.) = 2.2046 lb.
1000 kilograms = 1 metric ton (M.T.) = 2204.6 lb.

Measures of Capacity

10 milliliters (ml.) = 1 centiliter (cl.)
10 centiliters = 1 deciliter (dl.)
10 deciliters = 1 liter (l.) = 1.06 quart

Scientists of every country use the metric system. Many people in the United States who are engaged in commerce with foreign countries where the metric system is in use would be glad to see this system adopted by their country. Several attempts have been made to establish it by act of Congress as the official system of weights and measures. It is possible that before many years the people of the United States, like those on the continent of Europe, will be buying milk by the liter instead of by the quart, cloth by the meter instead of by the yard, and meat and groceries by the kilogram instead of by the pound (Fig. 75).

Self-test on Scientific Principles. Give one or more original examples illustrating this principle: "Matter can be changed, but it cannot be either created or destroyed."

Self-test on Problem VII-A. (*Do not write in the book.*) 1. *Most* of the objects in this room which I can see are matter.

2. There are *few* kinds of matter which cannot be weighed.

3. There are *no* kinds of matter which cannot be seen.

4. An example of organic matter is (1) concrete; (2) gold; (3) a feather; (4) a tin can; (5) lead pipe.

5. The juice of grapefruits and of oranges is *a base.*

6. All matter is made up of __(?)__, which are themselves made up of one or more __(?)__.

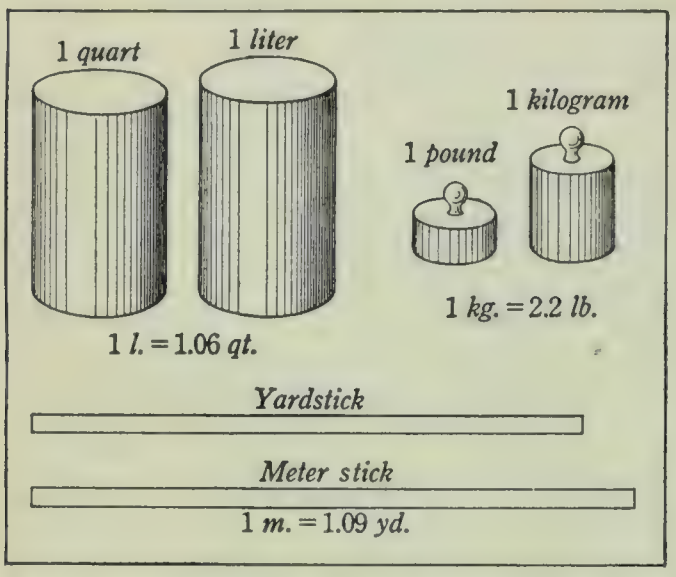


FIG. 75. Comparing English and metric units. **Question for Debate:** *Resolved,* That the metric system should be adopted for general use in this country

7. The tearing of one's clothes is an example of *chemical* change.

8. The burning of one's clothes is an example of __(?)__ change.

9. Whenever two or more elements combine to form a new substance every portion of which is exactly like every other portion, the new substance formed is called a *mixture.*

10. If sugar and sand were stirred together, the result would be *an element.*

11. A meter is *less* than a yard, a liter is *more* than a quart, and a kilogram is *more* than a pound.

Problem VII-B · What are Some Important Properties of Matter?

***All matter has inertia.** When you are running and stub your toe, you fall forward because your feet are suddenly stopped, but the inertia of the upper part of your body keeps it moving ahead. An automobile gains speed slowly because its inertia tends to keep it where it is, making it hard to start; but, once it is started, it cannot be stopped instantly, because its inertia tends to keep it going (Fig. 76). Inertia is the property which keeps a moving body moving in the same direction and at the same speed until something stops it, and which keeps a motionless body motionless until something makes it move.

Experiment 21. Can you explain these two "tricks"? (1) Place six or eight books in a pile. Quickly pull the bottom book from under the

rest. If you do this quickly enough, the rest of the books simply drop down without falling apart. Explain. (2) Place a coin upon a card over the open end of a water glass. Quickly snap the edge of the card (Fig. 77). What happens? Explain.

Fig. 76. Using science in sports. The man runs rapidly, then jumps as high as he can. Can you explain why he continues to go forward?

All matter when it is whirling has centrifugal force. Many automobile accidents occur because the automobile skids off the road when it reaches a curve while going at high speed. It tends to continue in the same direction in which it was going when it reached the curve. If lemonade is stirred round and round in a pitcher, the liquid likewise is forced outward from the center of the pitcher. Similarly, if you tie a piece of lead or a stone to a string and then whirl the lead or stone round your head while holding the end of the string, the weight will pull harder and harder against the string the faster it is whirled. The string may even break. If it does, the lead or stone will start off in a straight line.

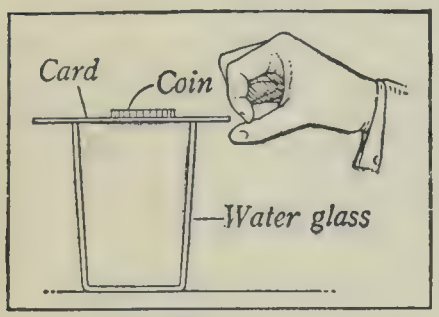


Fig. 77. Would the result be the same if the card were slowly pulled off as when it is snapped off? Explain

These are examples of centrifugal force. Centrifugal force is the tendency for all parts of a whirling body to move outward from the center. Centrifugal force is not really a force, such as a push or a pull. Centrifugal force is due to inertia.

***All matter is attracted by gravity.** If an object is dropped, it falls downward, that is, toward the center of the earth. The earth attracts every object on or near it (Fig. 78). This attraction is called gravity. The more matter a body has in it the greater its weight, because gravity pulls upon every atom in the body. Nobody yet knows what gravity, or gravitation,[1] is or what is its cause. We shall learn in our study of astronomy, however, that heavenly bodies attract each other, and that this gravitational attraction is the force that holds the earth and the other planets in their paths round the sun.

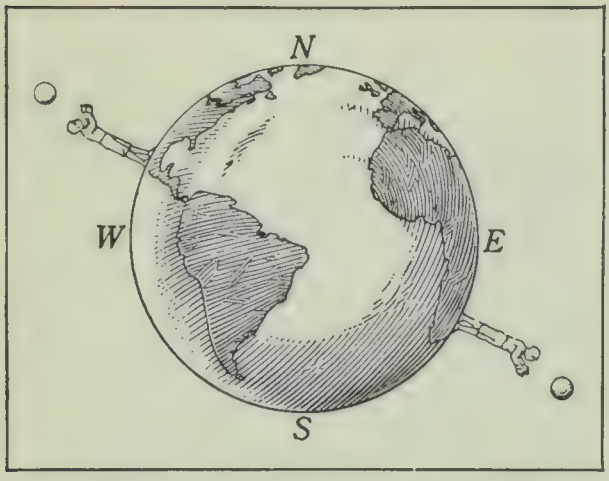


FIG. 78. Imagine two boys, one in the United States and the other halfway round the world from him. Each tosses a ball "up" in the air at the same moment and catches it as it comes "down." Do the two balls move in the same direction or in opposite directions? Suppose people in Alaska, France, Australia, and Argentina are all looking "up" at airplanes at the same time. Do they all look in the same direction? Which direction is "up"?

***All matter has density.** It is common to speak of such substances as cork and feathers as being light, and of such substances as gold and lead as being heavy. Usually, however, when people speak of one substance as being heavier or lighter than another, they are comparing equal volumes of the two substances. A more scientific statement is that one substance has a greater or a smaller density or specific gravity than the other. In the English system of measures, the density of any substance is the number of pounds a cubic foot of that substance weighs. Thus, the density of water is 62.4 pounds per cubic foot, because a cubic foot of water weighs 62.4 pounds. The density of ice is 57.2 pounds per cubic foot. Scientists express density in metric units. In the metric system the density of any substance is the number of grams that a cubic centimeter of that substance weighs (Fig. 79).

[1] *Gravitation* (grav i ta'shun) : the attraction any body has for every other body. *Gravitational* (grav i ta'shun al) : due to gravity (see Glossary).

Sometimes the term *specific gravity* is used instead of *density*, although the terms do not have the same meaning. The specific

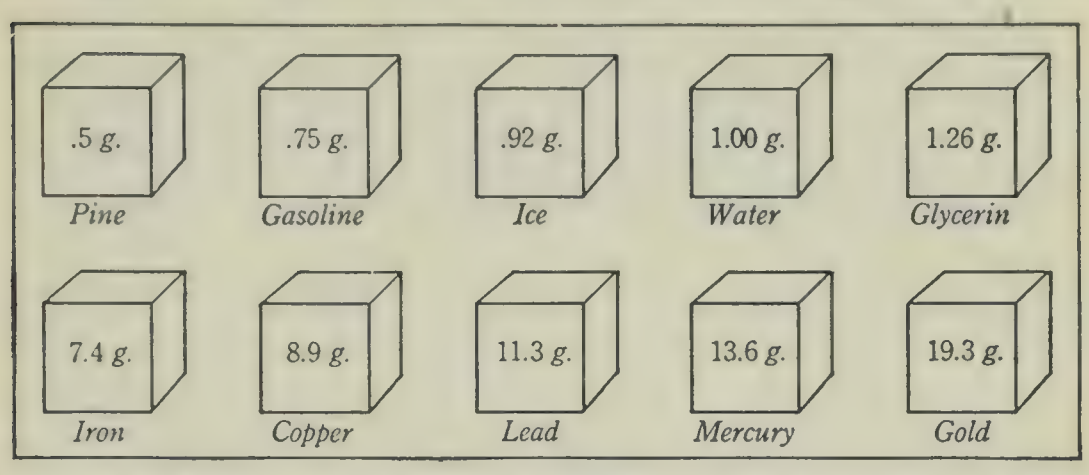


FIG. 79. Each of these cubes is exactly one cubic centimeter in volume and weighs the number of grams indicated on its face. The density of mercury is 13.6 grams per cubic centimeter. What are the respective densities of the other substances? In which of these liquids would ice float? How many of these substances would float in mercury?

gravity of a substance is its weight compared with the weight of an equal volume of water. Thus the specific gravity of ice (Fig. 80) is 0.92, which means that a cake of ice of any size or volume weighs 0.92 as much as an equal volume of water. As measured by the metric system, the density and the specific gravity of any substance are equal.

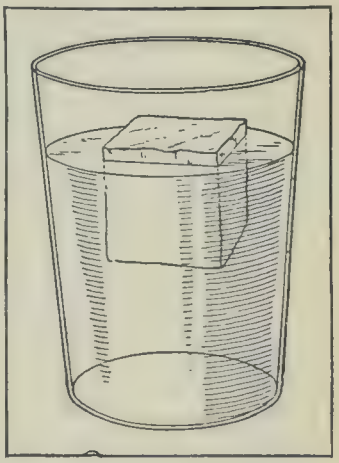


FIG. 80. If the specific gravity of ice were more than 1.00, would it float in water? Explain

The submarine[1] furnishes a good illustration of density and specific gravity. When the submarine is floating on the surface (Fig. 81, *A*) it has, like any other boat, an average density and specific gravity less than the density and specific gravity of water. The average density and specific gravity of the submarine must be increased before it can sink below the surface. Water is therefore allowed to enter the ballast tanks (Fig. 81, *B*) until the average density and specific gravity of the submarine are only slightly less than the density and specific

[1] *Submarine* (sub ma reen'): under the ocean; a ship which can travel beneath the ocean surface.

gravity of water. The submarine now barely floats. By means of its diving rudders it may now submerge[1] and return to the surface as desired. Before the submarine can float upon the surface again its average density and specific gravity must be reduced. This reduction is accomplished by forcing the water out of the ballast tanks by means of compressed air.

Matter has cohesion and adhesion. We know that water molecules stick together to form drops, that the molecules of iron stick together to form bars or other pieces instead of falling apart in a powder, that the molecules of chalk stick together in a piece of chalk, and so on. When molecules of the same kind stick together, they are said to cohere. Cohering, or cohesion as it is usually called, is therefore the sticking together of the same kind of molecules.

We know also that molecules of one kind often stick to molecules of another kind. Thus water sticks to the surfaces of most objects, making them wet; chalk sticks to the surface of the blackboard; oil sticks to the surfaces of parts of machinery. When molecules of different kinds stick together, they are said to adhere. Adhering, or adhesion as it is usually called, is therefore the sticking together of different kinds of molecules.

Self-test on Problem VII–B. (*Do not write in the book.*) **1.** If you give a chair a push, it continues to slide for some distance across the floor because of its _ _(?)_ _.

2. Mud flies off a moving automobile wheel because of _ _(?)_ _.

3. Bodies fall to the earth because of *inertia*.

4. A cubic foot of ice weighs 57.2 pounds. The _ _(?)_ _ of ice is therefore 57.2 pounds per cubic foot.

5. Mud sticking to an automobile tire is an example of *cohesion*.

6. It is difficult to pull apart substances like iron or glass, because of the _ _(?)_ _ of their molecules.

7. The denser a body is the *less* it weighs.

Self-test on Scientific Principles. Can you explain and illustrate with an automobile and a truck this scientific principle: "The heavier a body is, the greater is its inertia"?

Can you illustrate it with an original example?

[1] *Submerge* (sub merge'): to go beneath the surface of a liquid.

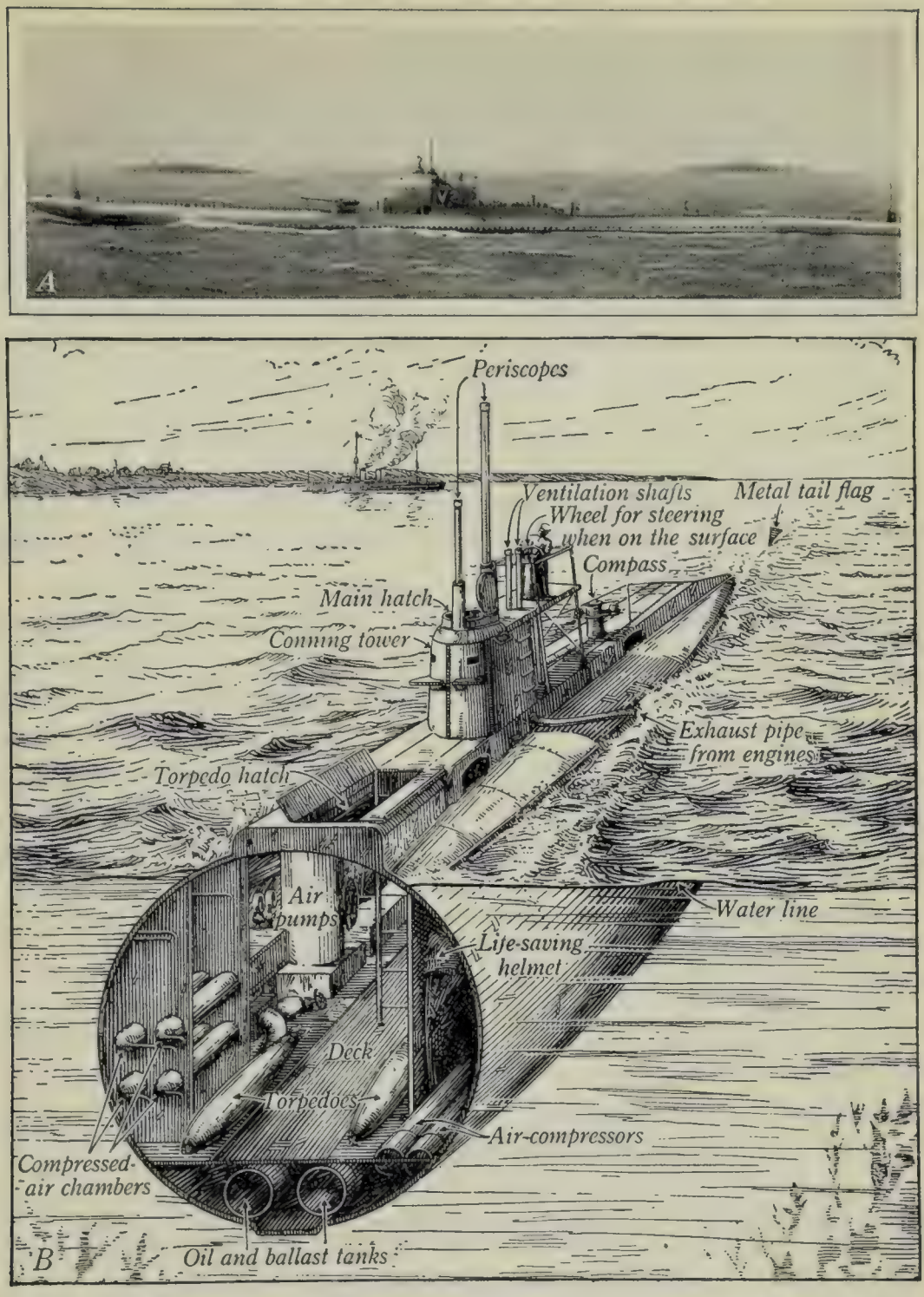


FIG. 81. *A*, a United States submarine on the ocean surface; *B*, diagram of submarine almost submerged.[1] What might happen if the average density and specific gravity of the submarine became greater than those of the water?

[1] Part *B* is from Millikan, Gale, and Pyle's *Elements of Physics*.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. How many examples other than those in the book can you give of matter which exists in all three states?

2. State which of the following are examples of adhesion and which are examples of cohesion: (1) sugar in a piece of candy; (2) candy sticking to your fingers; (3) glue holding two pieces of paper together; (4) glue in a tube.

3. What chemical and physical changes are taking place in Fig. 16, p. 30?

4. Tell which of the following are physical changes and which are chemical changes: (1) dissolving sugar in hot coffee; (2) freezing ice cream; (3) making carbon dioxide (Experiment 6, p. 33); (4) rusting iron; (5) decaying animal and vegetable matter; (6) making a partial vacuum; (7) slicing meat.

5. Water always flows from higher to lower ground and sinks into the ground. Explain.

6. Explain why mud and water are thrown off by the tires of moving automobiles.

7. If this country were to adopt the metric system, should we need to throw away all our grocers' scales, or should we be able to weigh kilograms, metric tons, etc. with the same scales we now have by changing the dials or the balancing weights of the scale? Explain.

8. How many examples of cohesion and adhesion can you see in the room where you are now sitting?

9. How many practical uses of the force of gravity can you name?

10. What would happen if the earth should suddenly lose its force of gravity?

11. What changes would have to be made in the dial of an automobile speedometer which registers miles in order to make it register kilometers?

12. Tornadoes (extremely violent winds) have been known to drive straws into tree trunks and boards through steel structure. Explain.

Exercise on Scientific Method and Scientific Attitudes. ARISTOTLE, a famous Greek philosopher (384 B.C.–322 B.C.), taught that the heavier a body is the faster it will fall. So great was the influence of Aristotle's teachings that nobody challenged the truth of this statement for nearly two thousand years. In the sixteenth century GALILEO GALILEI (1564–1642), an Italian scientist, questioned this generally accepted idea about falling bodies. He decided to find out by experiment whether it was true. He dropped objects of various sizes and weights from the Leaning Tower of Pisa. When he observed that they all fell at the same speed, he an-

nounced his discovery to the students and professors of the University of Pisa. They treated him and his statements with scorn, and even when he showed them that a half-pound weight and a hundred-pound cannon ball when dropped together reached the ground at the same instant, they hissed him and accused him of being a magician. If Aristotle had stated something was true, they thought it was true no matter what experiments might show. They persecuted Galileo so bitterly that he was compelled to leave his native city. He became a professor in the University of Padua, where he continued his scientific work.

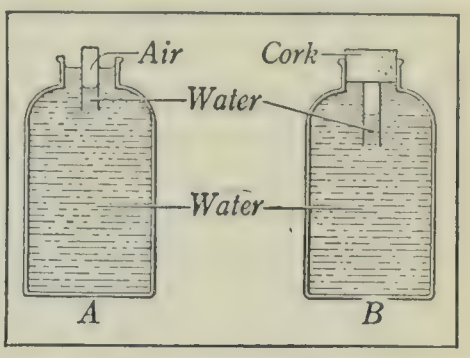


FIG. 82. Diagram of a "bottle submarine." Why in *B* must the bottom of the cork touch the surface of the water in the bottle?

What scientific attitudes (pp. 12 and 13) do these incidents show that Galileo possessed, and which did the professors and students not possess? What steps in the scientific method (p. 9) did Galileo use in proving wrong Aristotle's statements concerning falling bodies?

Exercises on Scientific Attitudes. 1. Can you solve this problem?

Minnie is twelve years old now. Sue is six years older than Minnie, who is four years older than Emma. If Emma will be seventeen a year from now, how old was Minnie a year ago?

Which of the scientific attitudes did you use in solving this problem?

2. Which of the five statements following this problem would a scientist be likely to consider best? Which of the scientific attitudes are related to this problem?

A magazine has printed a signed letter from a famous ball-player who writes that a certain patent medicine has done wonders for him and will cure anybody who has the same illness that he had.

a. The medicine has no merit whatever.

b. The ball-player's cure may have been due to something else besides the medicine.

c. The medicine may be helpful in certain cases.

d. The medicine doubtless has great merit.

e. The ball-player may have sold his signature without ever having taken the medicine.

Exercise on Scientific Method. Sir ISAAC NEWTON (1642–1727) was a British scientist and mathematician who is noted for many famous scientific discoveries. Probably the story of his discovery of the laws of gravitation is most famous. While seated alone in his garden he saw an

apple fall to the ground. Immediately he thought that the same force which pulled the apple to the ground also caused objects to fall from church spires and from mountain tops. Why then, he thought, might it not be the same force which holds the moon and the planets in their orbits? From this beginning he worked out the laws of gravitation, which have been of enormous importance in the science of astronomy. Newton also discovered the laws of motion, and that sunlight is composed of many colored beams. Also he invented the calculus, which those of you who continue your education in mathematics will study in college.

What phases of the scientific method (p. 9) are illustrated in this story of Newton and the apple?

Project.[1] To make and study a "bottle submarine." Fill a strong bottle, such as a pop bottle, a catchup bottle, or an olive bottle, entirely full of water. Fill another *very small* bottle about half full of water. Keeping your little finger over the mouth of the small bottle, invert it in the larger one so that the small bottle barely floats, bottom up, in the big one (Fig. 82, *A*). You may need to try several times, using a different amount of water in the small bottle each time, before you get the smaller bottle to float in the way shown in the figure. *Lightly* push a cork into the larger bottle, so as to force the smaller bottle down into the larger one (Fig. 82, *B*). The smaller bottle now represents a submarine at the surface of the ocean. Press down firmly upon the cork. What happens? Can you make the submarine go down or come up by changing the pressure on the cork? As you press upon the cork, carefully observe the submarine. Release the pressure on the cork and again observe the submarine. Can you explain why it sinks and rises? If you have been successful in carrying out this project, you have illustrated several of the scientific attitudes (see pages 12–13). Can you name these?

Carve the figure of a man out of wood. Put tacks on its feet so that it will barely float. Can you make it sink and rise in the bottle in the same way that you did the "bottle submarine"?

Special Report. Prepare a discussion of the history, advantages, and uses of the metric system.

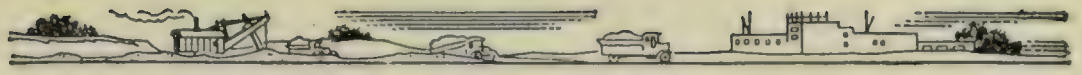
Questions for Debate. 1. *Resolved*, That physical changes are more important in our daily lives than chemical changes.

2. *Resolved*, That the metric system should be adopted immediately in this country.

Book for Reference

Collins, A. S. and V. D. Boys' Book of Submarines. Frederick A. Stokes Company, New York.

[1] This project was suggested by Mr. M. R. Van Cleve.



Chapter VIII · How Energy is Used in Doing Work

Questions this Chapter Answers

How is the control of energy related to human progress?
What are kinetic and potential energy?
Of what importance is the sun as a source of energy?
What are some other important sources of energy?
What is the principle of conservation of energy?
How is work related to energy, force, friction, and weight?

Problem VIII–A · What are the Nature and the Importance of Energy?

Man learning to control energy. Ages ago man learned that merely with his own hands and body he could not do many things which he wanted to do. Being more intelligent than the lower animals, he sought ways of securing the use of other stores of energy besides his own. Little by little he learned to tame various kinds of animals and to train them to do the heavier work for him. When he was successful in his human combats he sometimes made captives of his enemies and made them use their energy in working for him (Fig. 83). Little by little he learned to make use of some of the natural sources of energy. He learned to make the water from streams turn his rude mills. He learned to use the energy of fire to cook his food. Until very recently, however, he still depended for most of his energy upon men and animals. Within recent times scientists have learned to know and to use hitherto-unknown sources of energy, such as electricity[1] and the energy of radium.

***Kinds of energy.** As was stated in Chapter I, any portion of matter (for example, an animal, a rock, a boilerful of steam, or whatever it may be) has energy if it is able to move or to cause

[1] *Electricity* (e lek tris'i ty): the form of energy appearing in electric currents.

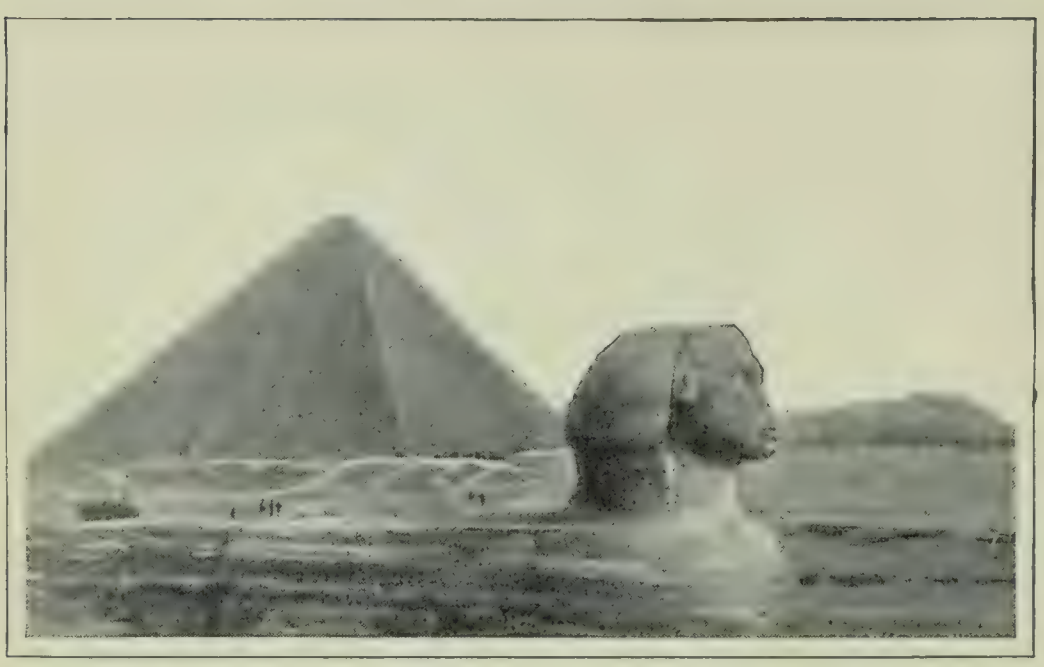


FIG. 83. The Great Pyramid of Egypt was built as a place for burials in 2900 B.C. under the direction of an Egyptian king who used the energy and the hand labor of thousands of slaves. What became of the energy used in raising the huge blocks of stone of which the pyramid is made?

something else to move. Some bodies of matter have energy because they themselves are moving, and by striking other objects could cause them to move. Other bodies of matter, which are not themselves moving, have energy stored in them because of their chemical nature or because of their position or condition. The energy possessed by moving bodies of matter is called kinetic energy. Stored energy, or energy of position or condition, is called potential energy (Fig. 84). When you kick a football your foot has kinetic energy, because it is moving and causes the football to move. The moving football has kinetic energy and knocks the molecules of air aside as it travels through the air. When it is above the earth it also has potential energy, because it is in position to fall. Finally all its energy, both kinetic and potential, is used up and it comes to rest on the ground. Wind possesses kinetic energy because as it moves it can move ships and windmills. Gasoline, coal, cooking gas, and food are all forms of potential energy because of their chemical nature.

Potential energy. Bodies may have potential energy because of their chemical nature or because of their position or con-

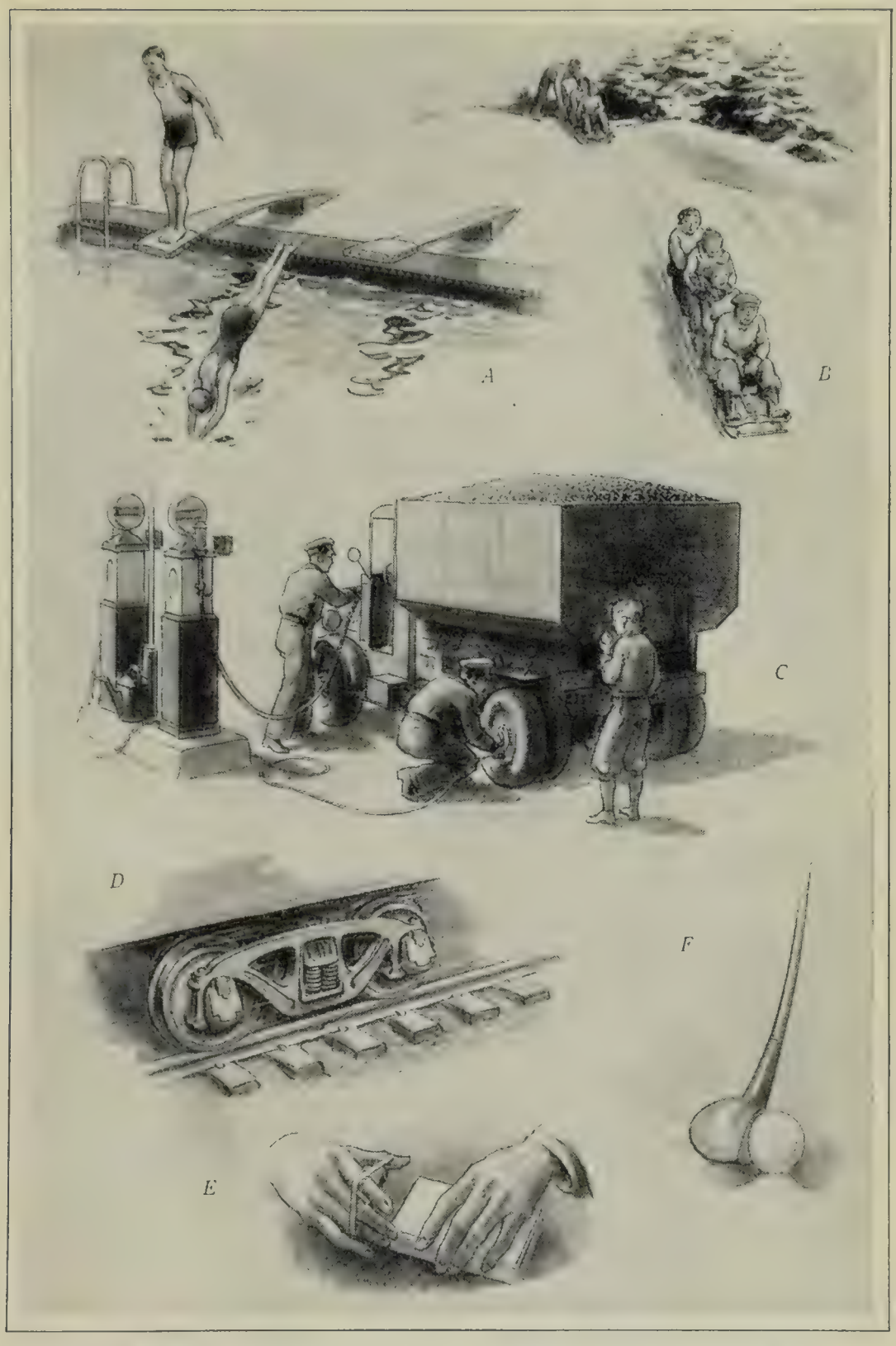


FIG. 84. What examples of kinetic and potential energy can you find in these pictures?

dition. They have potential energy not only when they are in position to fall but also when they are in position to roll or to slide, or when they are under a strain because they are stretched, bent, twisted, or compressed. Examples of these forms of potential energy are a rock which is on the top of a hill and which therefore can roll down the hill; a stretched rubber band, because if one end is released it can do work upon itself or upon something else as it contracts; a watch spring after it has been wound, because as it slowly unwinds it is in condition to move the wheels of the watch; a bent bow, because it is in condition, if released, to make an arrow fly through the air; compressed air, because it is in condition to move and to cause objects to move when it is released.

*Sources of energy. The moon is the source of a small portion of the earth's energy, since it is the principal cause of tides. The earth possesses some energy of its own in its heated interior. These two sources are of little importance, however, compared with the enormous stores of energy received directly and indirectly from the sun. The earth receives only an exceedingly small part of all the energy which the sun is constantly sending out in all directions through space. Yet this energy that we receive from the sun furnishes us with heat and light, without which no life would be possible. The heat energy from the sun causes unequal heating of the different parts of the earth, thus causing the winds and the ocean currents. It also sends us another form of energy which produces important chemical changes, such as those in photography and the fading of cloth and wallpaper. It evaporates water, thus making possible the rains, the streams and rivers, and the waterfalls. The sun's energy enables green plants to manufacture food and thus it makes possible all the food in the world.

The most important sources of energy in industry are coal, natural gas, petroleum, and water power. Of these the first three are all potential energy; the last is potential energy when it is stored in reservoirs and kinetic energy when it is turning water wheels. We now know of several forms of energy besides stored (potential) energy and the energy of moving bodies (kinetic). Some of these are current electricity, radio, light, and heat. There are still others which are known and probably others not yet discovered.

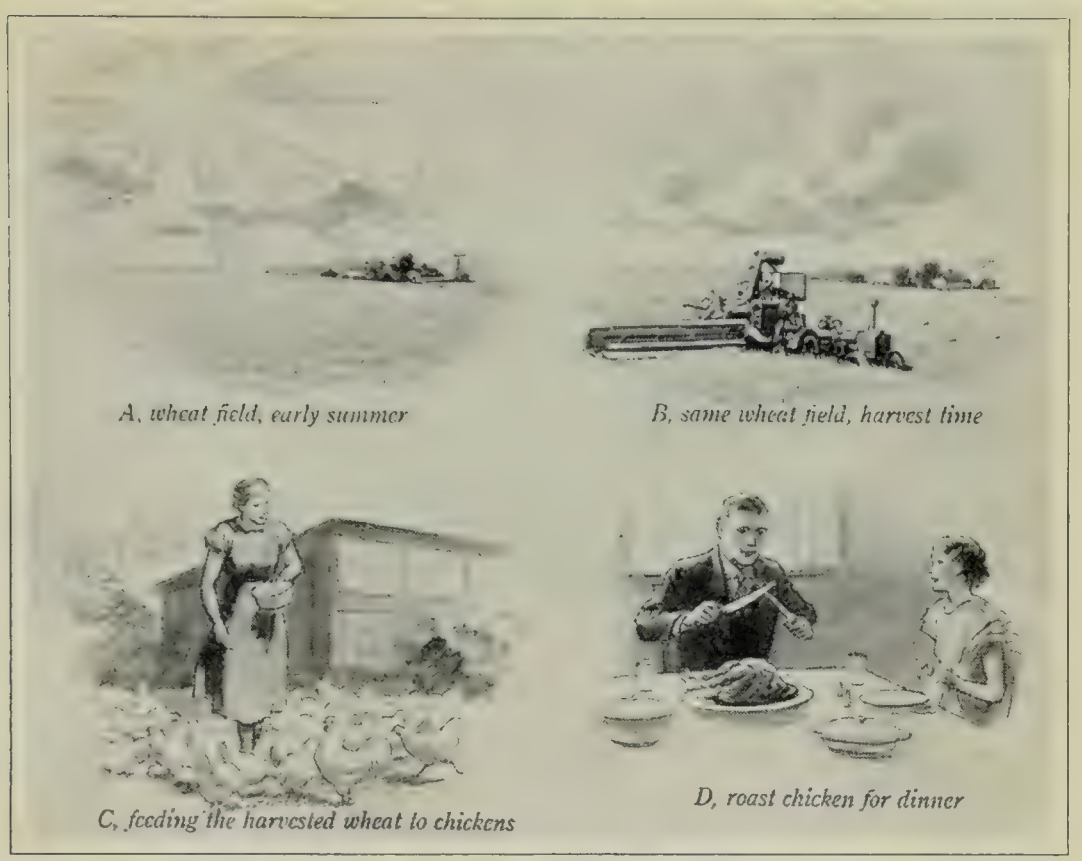

A, wheat field, early summer
B, same wheat field, harvest time
C, feeding the harvested wheat to chickens
D, roast chicken for dinner

FIG. 85. **Self-test on Scientific Principles:** Can you explain how this series of drawings illustrates each of these principles: "The sun is the source of nearly all the energy on the earth" and "Energy can be changed from one form to another, but it cannot be either created or destroyed"? How do the third and fourth pictures illustrate this principle: "Matter can be changed in form, but it cannot be either created or destroyed"?

***Principle of conservation of energy.** Energy cannot be created or destroyed but can be changed in form. This is known as the principle of conservation of energy. In this respect energy is like matter. Thus, before a gun is fired, the powder in it has chemical (potential) energy. While it is going off, this potential energy is transformed into several kinds of energy, such as heat, light, sound, and the kinetic energy of the moving bullet. The gun also has potential energy while it is being held above the ground. This potential energy is transformed into kinetic energy when the gun is being lowered from the shoulder. We burn coal (potential energy) to produce steam (heat energy) to turn the armature of an electrical generator, or dynamo (kinetic energy), thus producing electricity (electrical energy), which lights lamps (light and more heat energy), turns armatures of electric motors

in vacuum sweepers, fans, washers, and the like (kinetic energy), heats flatirons and stoves (heat energy), and so on (Fig. 85).

New uses and sources of energy. New uses of energy are constantly being discovered and applied to every portion of modern life. Scientists are not content merely with inventing new ways of using the sources of energy which are already at hand. They are constantly seeking to discover new sources. We might summarize[1] the importance of energy by stating that some of the chief problems of scientists today are (1) to discover hitherto-unknown sources of energy, (2) to invent new uses of energy by which to make the world a more pleasant and more convenient place to live in, and (3) to enable us to get more value out of the energy we use.

Self-test on Problem VIII–A. (*Do not write in the book.*) 1. A moving automobile always has *potential* energy.

2. A loaf of bread and a gallon of kerosene are both examples of _ _(?)_ _ energy.

3. The *moon* is the source of nearly all the energy on the *earth.*

4. When a ton of coal is burned, the _ _(?)_ _ is not lost but is changed to some other form of _ _(?)_ _.

5. Matter has *energy* only when it is able to move or cause *motion.*

Self-test on Scientific Principles. Can you give an original example to illustrate this principle: "Energy can be changed from one form to another, but it can be neither created nor destroyed"?

Problem VIII–B · What are Some Factors Involved in Doing Work?

***Energy, force, and work.** Whenever you push or pull some object, you exert a force upon it. An example of a force is gravity, which tends to pull all objects toward the center of the earth; in fact, a force is a push or a pull. Whenever you push or pull some object and succeed in making it move, or whenever you succeed in stopping some object that is moving, you have done work. In the strictly scientific sense you never do any work *unless* you

[1] *Summarize* (sum'a rize): to make a summary, that is, to bring together important points or ideas into a short list or statement.

FIG. 86. An ox-carriage in the Madeira Islands. Is there much or little friction when this vehicle is pulled along? Explain. The driver carries a piece of coarse cloth soaked in oil. He lays this cloth in front of one runner. After the sled has passed over the cloth he puts it in front of the other runner. Thus he reduces friction. Explain. Is more force required to move the sled before or after it has passed over the oil-soaked cloth? Explain

succeed in moving something or stopping something that is already moving. You may push or pull as long and as hard as you please, but if you do not succeed in moving the object upon which you are exerting the force, you have not done any work at all. Thus, you may study, or you may hold a heavy object above the floor, or you may push against the wall until you are exhausted, without doing any work whatever in the scientific sense, because you have not moved anything. In each case you have exerted force and have used up energy, but you have done no work. No work is ever done unless there is both force and movement. This scientific definition[1] of work may seem somewhat puzzling to you. It is, nevertheless, the definition which is used in connection with all engineering and all machines of every sort.

***Friction.** We think of the surface of a window glass or of a planed board as being perfectly smooth. It is not. No surfaces are perfectly smooth. Whenever two surfaces rub together, there-

[1] *Definition* (def i nish'un): an explanation or description of a word or thing.

fore, there is always resistance[1] to the motion. This resistance to the movement of one object upon the surface of another is called friction. Thus there is friction whenever work is done. Also, the rougher the surfaces which rub together the greater is the friction between them.

*Effects of friction. Friction always produces two effects: (1) some of the mechanical energy of the moving object is always transformed into heat energy and (2) some of each surface is always worn away. Thus when you rub your finger rapidly back and forth on your sleeve, both the cloth and your finger become hot. The rougher the cloth or the faster you move your finger the warmer both the cloth and your finger become. Try this. If you continued the rubbing long enough, the cloth would wear through and the skin of your finger would be worn off. If you have experienced what happens when one slides rapidly down a rope, you have had a good illustration of the facts stated above.

Desirable and undesirable friction. We are apt to think of friction as something which is always undesirable, since it uses up some of the energy and since it causes machinery to wear out. It is true that we usually try to reduce friction in machinery. One way to do this is to put oil or grease into the parts that rub together (Fig. 86). The oil reduces the friction because (1) it keeps the hard surfaces from touching; (2) it fills uneven places in the surfaces, thus making them smoother; and (3) it provides yielding surfaces in place of the hard unyielding surfaces. Another way to reduce friction is to make things roll rather than slide. Thus small wheels sometimes are put on furniture legs; wheels instead of sled runners are put on railroad cars; ball bearings and roller bearings are used in machines of many kinds (Fig. 87).

*But although too much friction is undesirable, friction is very important and necessary in our daily life. Thus the housewife uses a lemon-grater to increase the friction when she wants to wear away the skin of the lemon. If there were no friction between your shoes and the floor, you could not walk out of the room. If there were no friction, the nails in the ceiling would fall out. If there were no friction, the automobile brakes would not stop the wheels.

[1] *Resistance* (re zis'tance): opposition to motion, action, force, or effort.

Relation of force to weight. When you lift an object you must exert upon it a force equal to its weight.[1] Thus, when you lift a

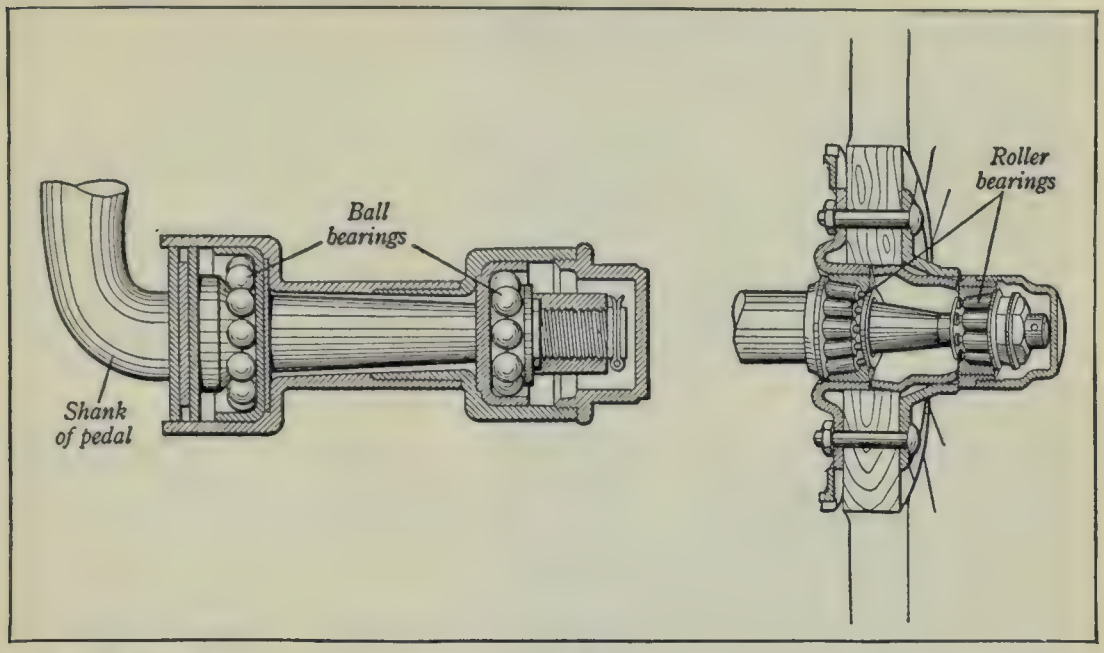


FIG. 87. Why are ball bearings put into this bicycle pedal, and why are roller bearings put into this automobile wheel? How many machines can you name in which you have seen ball bearings or roller bearings?

book weighing two pounds you exert a force of two pounds. In Fig. 88, *A*, the boy is exerting a force equal to the weight of the wagon and its load, because he is lifting them. If you move an object without lifting it, you sometimes exert a force smaller than the weight of the object and sometimes a force greater than its weight. Thus, in Fig. 88, *B*, the boy is exerting a much smaller force than the weight of the wagon and its load, because he needs to exert only enough force to overcome the rolling friction of the wheels on the walk. In Fig. 88, *C*, however, he is exerting a force much greater than the weight of the wagon and its load, because the wheels are half buried in the sand.

***Measuring work.** To find how much work is done upon an object which is moved, we multiply the force exerted in moving it by the distance it is moved. Thus force times distance equals work. In Fig. 88, *A*, if the curb is 1 foot above the street, the boy

[1] Actually in lifting a body it is necessary to exert a force slightly greater than the weight of the body. But the extra force required would be so little more than the weight that we need not consider it, unless the lifting is rapid.

in lifting his 50-pound wagon 1 foot does $1 \times 50 = 50$ foot-pounds of work. In Fig. 88, *B*, each time that he pulls his wagon forward 2 feet while he exerts a force of 10 pounds, he does $2 \times 10 = 20$ foot-pounds of work. In Fig. 88, *C*, every time that he succeeds in pulling his wagon forward 2 feet while he exerts a force of 60 pounds, he does $2 \times 60 = 120$ foot-pounds of work.

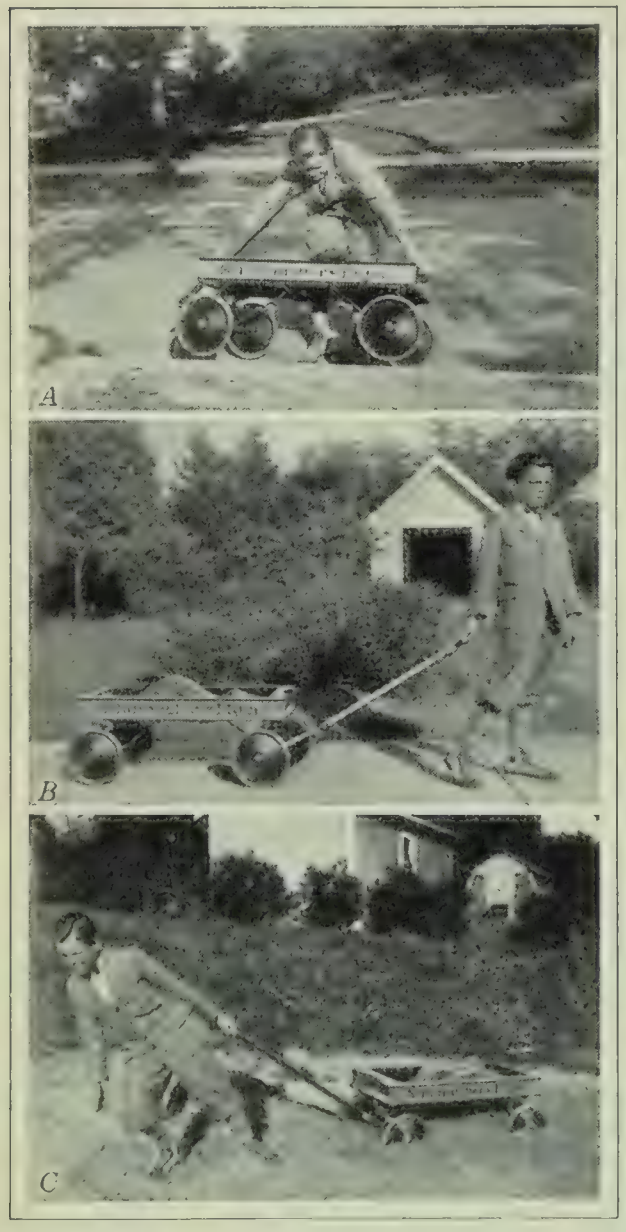


FIG. 88. Is the boy using energy and doing work as well as exerting force? Explain

Work is independent of time. The amount of work done in moving anything a certain distance is the same whether the object is moved quickly or slowly. Thus the boy does the same amount of work in pulling his wagon a mile whether he covers the distance in a half hour or three hours.

Force, work, inertia, and friction. The amount of work is greater in starting a body and then moving it than in moving it an equal distance after it has been started. Because of the inertia of the body at rest, extra force is required in overcoming this inertia. Thus, in Fig. 88, *B*, the boy would do more than 20 foot-pounds of work in moving his wagon the first 2 feet, because he would have to exert more than 10 pounds of force in starting it. Also, the greater the friction the more the work done in moving a body a certain distance, because

more force is necessary to keep the body moving. Thus, in Fig. 88, *C*, the boy does six times as much work in pulling his wagon 2 feet through the deep sand as he does in pulling it 2 feet on the sidewalk, because he must then exert six times as much force to overcome the friction of the wheels in the sand.

FIG. 89. The lineman has energy, exerts force, and does work. Explain. In what ways does he use friction to prevent his falling?

Self-test on Problem VIII–B. (*Do not write in the book.*) **1.** If you were to try to lift a truckload of coal with your hands, you would be exerting a _ _(?)_ _ but you would be doing no _ _(?)_ _.

2. If while an automobile is going rapidly the brakes are set so that the wheels slide, the tires become hot and are worn away rapidly because of (1) inertia; (2) friction; (3) work; (4) energy; (5) molecules.

3. Chains are sometimes put on automobile tires in traveling through deep snow or heavy mud or sand in order to increase the _ _(?)_ _.

4. If a truck can deliver a ton of coal in half the time a horse can deliver it in a wagon, the truck does (1) twice as much work as the horse; (2) half as much; (3) the same amount; (4) a little more; (5) a little less.

5. More force is required to start and to stop an automobile than to keep it going at unchanging speed because of its _ _(?)_ _.

6. *More* work is done in starting an automobile than in keeping it running at unchanging speed.

Self-test on Scientific Principles. Can you trace, step by step, back to the sun the energy of an electric lamp? the energy in a loaf of bread? Can you state the scientific principle which applies to these two questions?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. How many examples of kinetic and of potential energy can you list in five minutes?

2. An automobile gets stuck in sand. Several men push on the automobile to get it out of the sand. At first they cannot move it. Are they exerting force? Are they expending energy? Are they doing work?

Justify your answers. Finally they succeed in moving the automobile. Do they do work then? Explain.

3. Why are sand and ashes sometimes spread on icy sidewalks?

4. How many examples of useful friction can you give? How many examples of undesirable friction?

5. The farther away the faucets are from the reservoir, the standpipe, or the pumping station, the less the pressure of the running water. Why?

6. If the lineman in Fig. 89 weighs 150 pounds and climbs 20 feet up the pole, how many pounds of force must he exert in lifting himself? How many foot-pounds of work must he do upon himself in climbing 20 feet? While he is climbing, what kind of energy has he? When he stops climbing, what kind of energy has he?

Exercise on Scientific Attitudes. You are given a locked padlock and a box containing several hundred loose keys, among which is the key that will unlock the padlock. You are in a hurry to unlock the padlock. Which of the following would probably be the best and quickest way to unlock it?

a. See whether the keyhole looks as if it would require a flat key or a round key to open it. Then try, one after another, all the flat keys or all the round keys until you come to the right key.

b. Try any key that your hand happens to touch. It is as likely to be the right key as any other in the box. If it doesn't happen to fit, toss it aside and try the next key that your hand happens to touch, and so on until you pick up the right one.

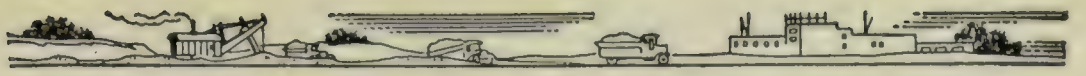
c. If it is a big padlock, pick out and try, one after another, only the large keys until you come to the right one; if it is a small padlock, do the same with the small keys.

d. Before trying any key in the lock, examine the keyhole carefully. Then pick out all the keys which look as if they would open the lock. Try the most likely-looking one of these first; if it does not fit, try the next most likely-looking one, and so on until you come to the right one.

e. Close your eyes, plunge your hand into the box of keys, and trust to luck to pick the right one. If you do not happen to get the right one the first time, do the same thing again and keep on doing it until you do pick the right one. You are certain to pick the right one sooner or later.

Which of the scientific attitudes (pp. 12 and 13) applies to this problem especially?

Project. Make a series of drawings, sketches, or cartoons illustrating the principle of conservation of energy. Mount your drawings on cardboard to serve as materials for a permanent classroom exhibit.



Chapter IX · Making Machines Help Us

Questions this Chapter Answers

How is progress in the development and use of machines related to progress in civilization?
How do machines help us to do work?
What are the characteristics and the uses of simple machines?
What is the relation of simple machines to compound machines?
What is meant by a labor-saving device?
What are efficiency and power?

Problem IX–A · Of What Importance to Progress are Machines?

Ancient and modern work. Ancient man did all the work he had to do by moving objects with his own hands. Later man forced his domestic animals or captives to carry and drag objects for him. Little by little, just as he learned to use stores of energy besides his own, he learned how to construct rude machines to assist him in making better use of energy. By means of these machines he was able to build better dwellings, to cultivate his fields better, to wage war more successfully — in fact, to do all his various tasks better and more easily. After many thousands of years man had learned to build such marvelous structures[1] as the pyramids of Egypt and the Colosseum of Rome. Even these were largely built by the work of animals and slaves with the help of a few rude machines. Only within recent times has man perfected and combined the various machines which make possible the great structures and the comforts of our everyday life. Even today, in many highly civilized countries much of the work is done by man or beast (Fig. 90).

***Uses of machines.** When asked to name some common machines, you doubtless think of such ones as the automobile, the airplane, the locomotive, the sewing machine, the farm tractor,

[1] *Structure* (struk'chur): something built, as a building, a bridge, or other work of engineering.

FIG. 90. Two ways of doing work. A vegetable dealer and an automobile in Granada, Spain. What advantages has the automobile over the donkey? What advantages has the donkey over the automobile?

the lawn mower, the concrete mixer, the derrick, or the elevator. When we examine these and other machines we find that in every case a machine transforms some kind of energy into kinetic energy or transfers kinetic energy from one point to another, since every machine moves its own parts, and usually also some other object, and hence does work. Thus, electric motors transform electrical energy into mechanical energy, as in electric washers, street cars, and vacuum sweepers. Steam engines or gasoline engines transform the potential energy of coal or gasoline into mechanical energy. Other machines change forms of energy, as light, moving air or moving water, and the sun's heat, into the mechanical energy of moving wheels, pumps, and the like. Machines such as water wheels, windmills, those used in factories, and many others transfer mechanical energy from one point to another. Also, some machines transform mechanical energy into electrical energy. Examples are turbines and steam or gasoline engines which operate electrical generators.

*Ways in which machines help to do work. Every machine serves one or more of the following purposes, though no machine can serve them all:

*1. Some machines enable us to overcome enormous resistances, that is, to move great weights by exerting much smaller forces. The electric shovel (Fig. 91) and the derrick are machines of this type. Such machines are said to sacrifice speed or distance in order to gain force, because the smaller force moves farther than the greater weight or resistance moves in the same time.

FIG. 91. A large electric shovel for moving coal. Note the size of the man compared with that of the shovel. Does this machine illustrate any ways except the first in which machines help us?

*2. Some machines enable us to do useful work more quickly than it could be done without them. The lawn mower, the egg beater, the elevator, and the concrete mixer are machines of this type. Such machines are said to sacrifice force in order to gain speed or distance.

*3. Some machines enable us to exert a force in one direction in order to move an object in another direction. The derrick and the lawn mower are machines of this type.

*4. Some machines enable us to do useful work much more evenly and accurately than it could be done without them. The sewing machine and the concrete mixer are machines of this type.

Self-test on Problem IX–A. (*Do not write in the book.*) 1. Machines are used to aid us in doing __(?)__.

2. When in use, machines always possess *potential* energy.

3. A machine which enables us to overcome enormous resistance by exerting a small force is the (1) bicycle; (2) automobile jack; (3) egg beater; (4) lawn mower; (5) windshield wiper.

4. Give an original example of a machine which serves each of the purposes described under "Ways in which machines help to do work."

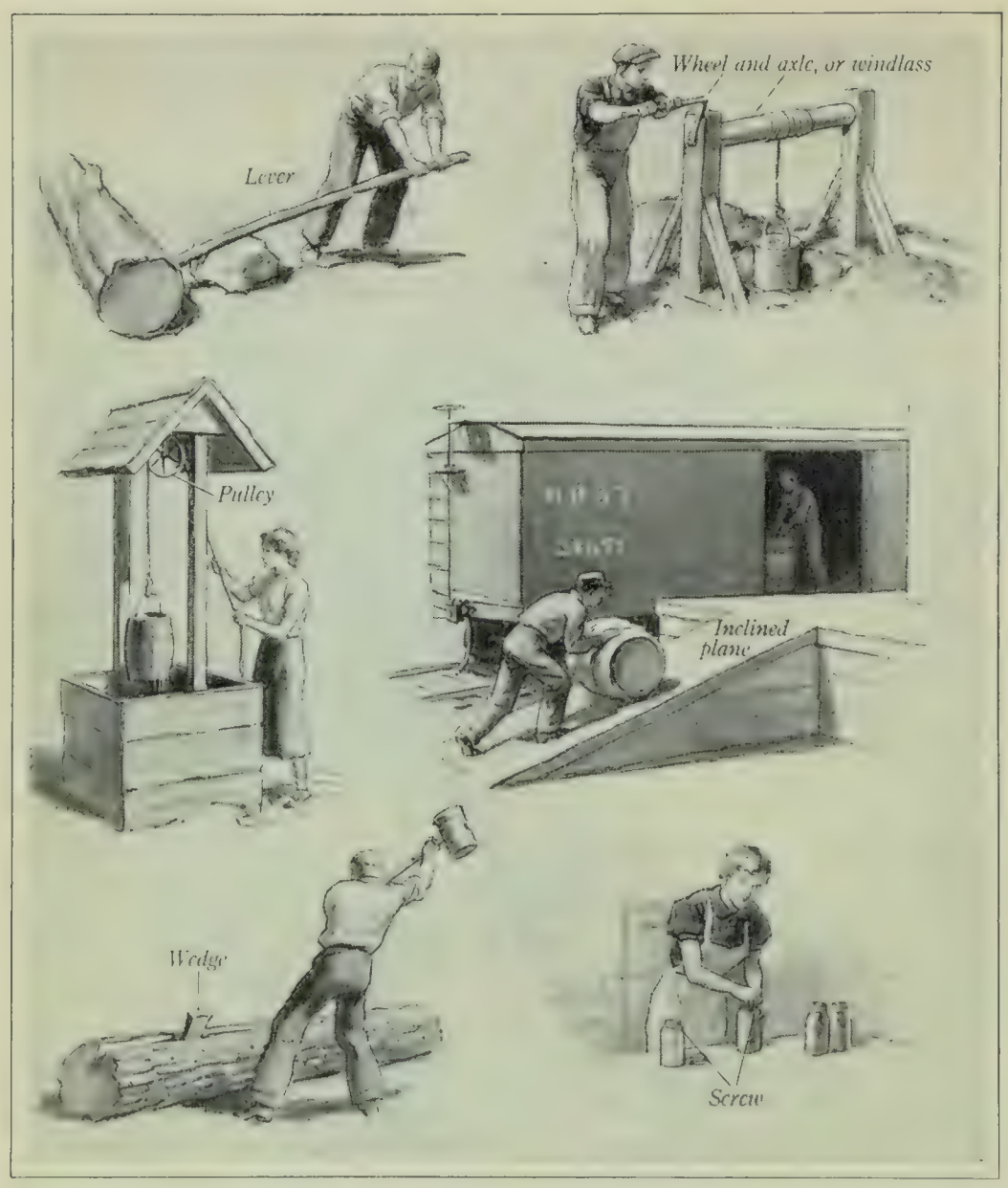


FIG. 92. Examples of the six types of simple machines. Can you give another example of each?

Problem IX–B · What are the Characteristics of the Six Types of Simple Machines?

***Types of simple machines.** We naturally think of machines such as those we have been discussing as if each were just one machine. Actually they are compound machines made up of many simple machines working together. When we examine the compound machines carefully, we discover that there are really

only six different types of machines. These six types are the lever, the pulley, the wheel and axle (or windlass), the inclined plane, the wedge, and the screw (Fig. 92). All compound modern machines are combinations of these six types.

***The lever.** Probably the first machine used by man was a club. A club is a lever. A lever is a stiff bar or pole which turns, or pivots,[1] upon a support. We call this pivoting support or point of a lever the fulcrum.

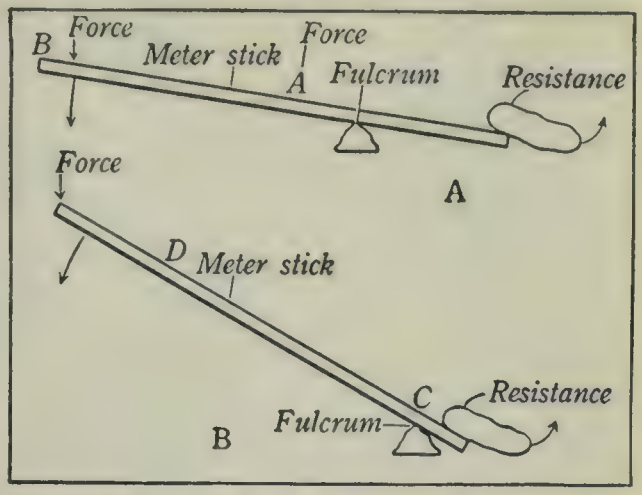


FIG. 93. In which of these two diagrams of a lever would a smaller force exerted at the end of the lever lift a 5-pound resistance?

Experiment 22. In using a lever, is a greater or a smaller force required when the force is exerted near the fulcrum than when the force is exerted farther from it? Is a greater force required when the fulcrum is moved nearer to the resistance than when the fulcrum is moved farther from it? Select an object weighing at least a pound to serve as the resistance, a block or stone to serve as the fulcrum, and a stick several feet long (for example, a thin board, a lath, or a meter stick) to serve as the lever. Place the resistance, the fulcrum, and the lever in the positions shown in Fig. 93, *A*. Press down on the lever at the point marked *A* with enough force to lift the resistance. Then, without changing the position of the fulcrum or the resistance, shift your hand to point *B* and again press down with enough force to lift the resistance. Repeat this experiment until you are sure you can answer correctly the first question at the beginning of this experiment. Now place the resistance, the fulcrum, and the lever in the positions shown in Fig. 93, *B*, with the fulcrum at the point on the lever marked *C*. With your hand at the extreme end of the lever press down with enough force to lift the resistance; then, without changing the position of your hand or the resistance, shift the fulcrum to the position on the lever marked *D* and again press down with enough force to lift the resistance. Repeat this experiment until you are sure you can answer correctly the questions asked at the beginning of this experiment.

[1] *Pivot* (piv'ot): to swing, like a hinge, on a point. The point also is called a pivot.

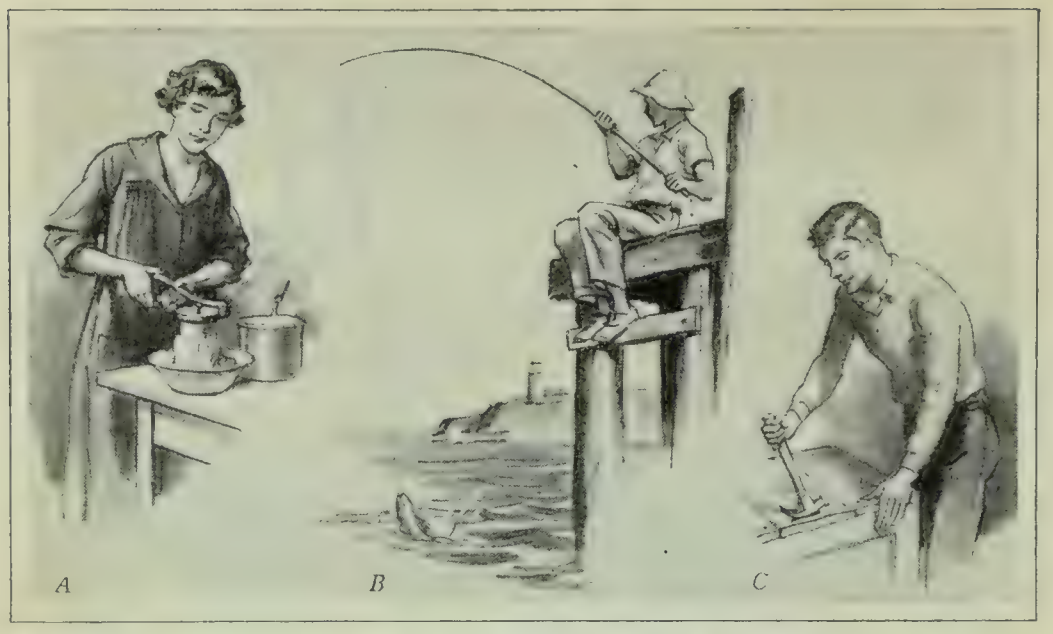


FIG. 94. Some common levers. How many purposes for which levers are used can you name?

Simple levers are not always exactly like those in Figs. 92, *A*, and 93. Sometimes the fulcrum is between the force and the resistance, as in those figures. Sometimes it is at one end, with the resistance between the force and the fulcrum, as in the potato ricer in Fig. 94, *A*. Sometimes it is at one end, with the force between the resistance and the fulcrum, as in the fish pole in Fig. 94, *B*. Sometimes the lever is crooked instead of straight, like the claw hammer in Fig. 94, *C*.

In the case of the claw hammer the force exerted by the hand is not nearly so great as the resistance of the nail, but the force moves much farther than the resistance. This statement is also true for the potato ricer: the hand (the force) moves farther and faster than the plunger (the resistance). With the fish pole the opposite is the case: the resistance (the fish) moves farther and faster than the force (the boy's right hand), but the resistance is not so great as the force; that is, the boy must exert more than two pounds of force to land his two-pound fish. When the force is less than the resistance, it must move farther and faster than the resistance. Thus speed is sacrificed in order to gain or increase force. If the resistance is smaller, it must move farther and faster than the force. Thus force is sacrificed in order to gain or increase speed.

FIG. 95. The fixed pulley and the movable pulley. Why is it better to have the pulley turn than it would be to have the rope slide over it without turning? Why is the applied force 55 pounds instead of 40 pounds?

We shall see that these last two statements about levers are true also for the other types of machines described in the following pages.

***The pulley.** The pulley was known at least as early as the time of ancient Greece. Archimedes[1] is said to have astonished the king and his court by moving ships with combinations of pulleys. A pulley is a wheel around the rim of which a rope passes. Fig. 95 illustrates two uses of the pulley; the pulley at the top is called a fixed pulley, because it remains where it is while being used to lift the weight, or resistance. The lower pulley is called a movable pulley, because it moves with the resistance. Fixed pulleys always serve one purpose only: they make it possible to exert a force in one direction in order to move a resistance in another direction (see 3, p. 143). An experiment will help you to understand how a single fixed pulley operates.

Experiment 23. With a fixed pulley is more or less force required to raise a body than the number of grams the body *weighs*? Arrange the materials as in Fig. 96. Pull down on the balance until the resistance

[1] *Archimedes* (ar ki me'dez): a famous Greek scientist and inventor (287 B.C.–212 B.C.)

(an object weighing about half a pound) rises slowly and steadily. Observe the reading of the balance. Repeat the entire experiment, using as the resistance a second object weighing at least a pound. Answer with a complete statement the question asked at the beginning of this experiment.

Exercise on scientific method (using check experiments). What were the check experiments in Experiments 22 and 23? What purpose did they serve?

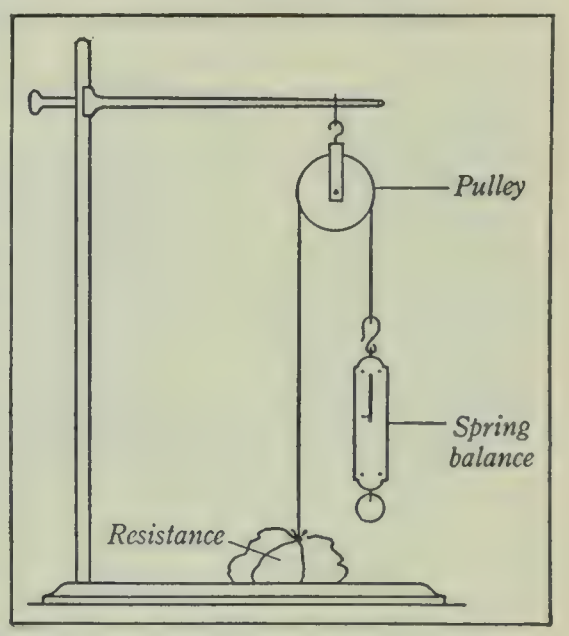


FIG. 96. Would more or less force be required to raise the resistance if the balance were attached to the string by its ring instead of by its hook? Explain

*In Fig. 95 the movable pulley with the box attached moves upward only half as fast as the man's hands move downward, because the man must pull two feet of rope through the fixed pulley for every foot that the box rises. Thus with the movable pulley speed is sacrificed to gain force. If there were no friction in these pulleys the man would have to exert a force of only forty pounds to lift the eighty-pound box, because the force moves twice as far as the resistance. Of course there is considerable friction in the two pulleys, and therefore the man must actually exert a force of fifty-five pounds.

*In moving heavy objects with pulleys, combinations of pulleys are used (Fig. 99). Each combination of pulleys is called a pulley block, and the arrangement of pulley blocks with their ropes is called a block and tackle. With a block and tackle a heavy resistance can be moved with a much smaller force, because the force moves so much farther than the resistance.

The wheel and axle, or windlass. With a wheel and axle (Fig. 97) the force is usually exerted on the rim of the wheel in order to move the resistance, or weight, that is attached to the axle. In the steering wheel the wheel is complete; but in the fishing reel we have only one spoke of the wheel, which is the handle

FIG. 97. Two familiar examples of wheel and axle. How many other examples of wheel and axle can you name?

E. G. Keller

FIG. 98. With the inclined plane are speed and distance sacrificed to gain force or is force sacrificed to gain speed and distance? Explain

of the reel, and all the force is exerted on the end of this one spoke. In both illustrations of the wheel and axle shown in Fig. 97 the force is much less than the resistance, because it travels much farther; in Fig. 102, *C*, p. 152, the force applied by the lever to the handle of the grindstone is greater than the resistance on the axle (the rim of the grindstone), because the rim of the grindstone travels farther than the force.

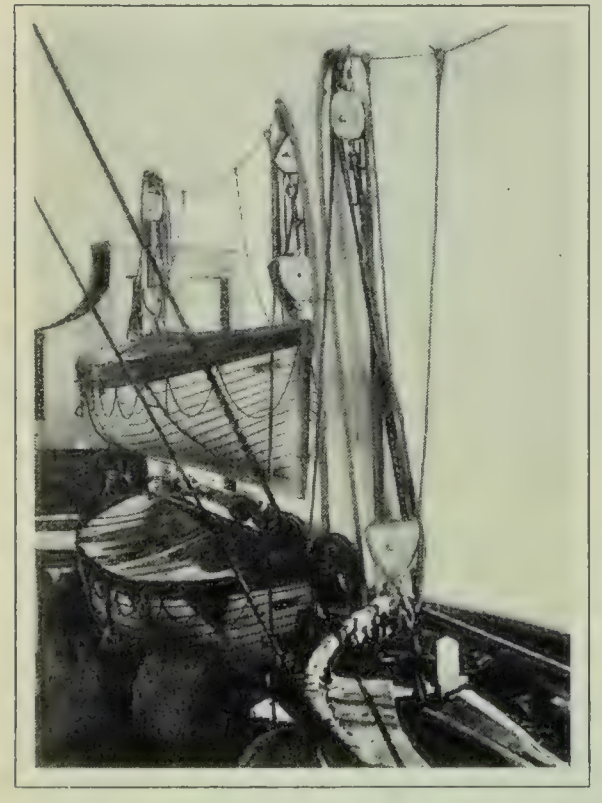


FIG. 99. Pulley blocks are used to raise and to lower the lifeboats of ships. Each block contains two pulleys. What advantage is there in having more than one? Which of the blocks are fixed and which are movable?

The inclined plane. The inclined plane is probably a more ancient invention than the pulley. It is believed to have been used by the Egyptians in dragging the great blocks of stone up the sloping sides of the pyramids in completing them. Less force is required to drag or push an object up an inclined plane than would be required to lift the object straight up from the ground. The reason is that the object travels a greater distance up the incline than it would travel if it were lifted straight up from the ground. A mountain road is made as an inclined plane (Fig. 98) in order to make the slope more gradual.

The wedge. The wedge (Fig. 100) is only a movable inclined plane. As it is forced into wood or other material it exerts a prying force *outward*. Thus it exerts a force in one direction to move a resistance in another direction. Also, the force applied to the wedge is less than the resistance (the prying force exerted outward by the wedge against the wood), but it travels much farther. Thus, with the wedge, speed and distance are sacrificed in order to gain or increase force.

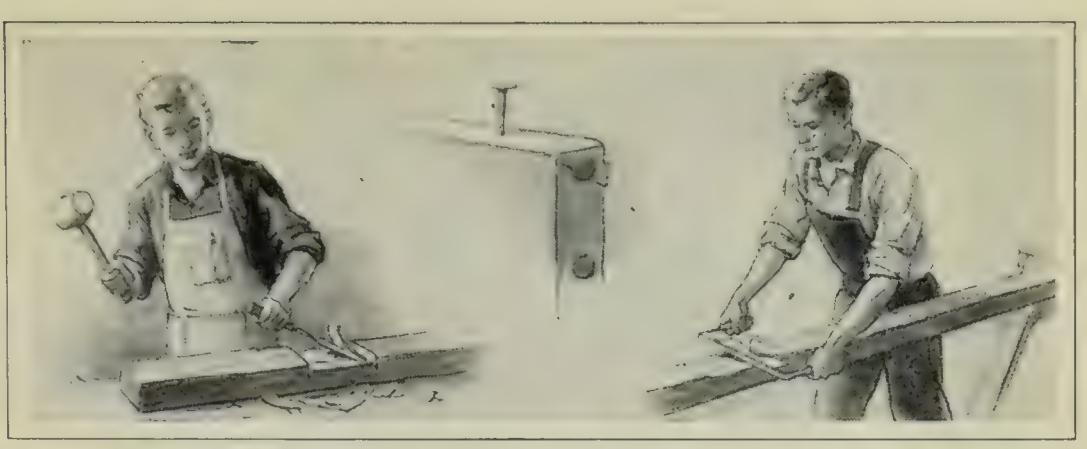


FIG. 100. The chisel, the tack, and the drawknife are wedges. Compare a chisel with an ax or a hatchet (see "To the Student," p. xvi). Can you think of other examples of wedges?

FIG. 101. Can you find three screws in *A*? Can you locate the screws in *B* and *C*? What other simple machine is combined with the inclined plane in the screw?

The screw. The screw is an inclined plane which winds round and round as it moves forward (Fig. 101). A screw always sacrifices

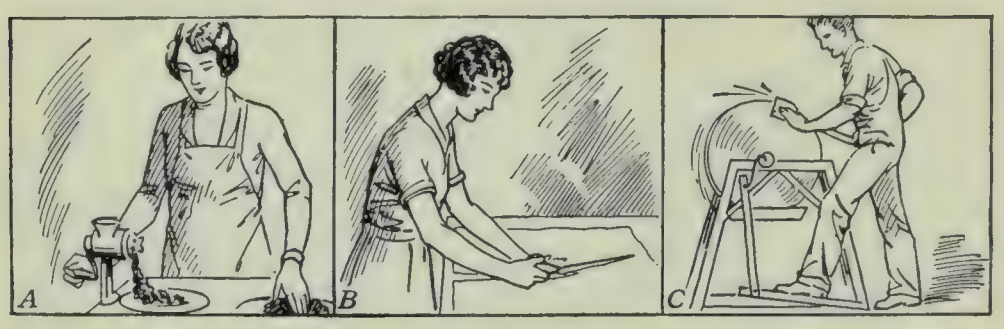


FIG. 102. Some compound machines. Explain the fact that the meat-grinder is a screw and a wheel and axle. What two machines are combined in the shears? in the treadle grindstone? Can you locate the force and the resistance in each of these machines?

speed to gain force. The gentler the slope of the spiral[1] the less the force exerted in raising the weight, but the force travels many times as far as does the weight. The propeller of a boat or an airplane is an example of a screw. It screws its way through the water, pushing the boat ahead of it, or through the air, pulling the airplane after it.

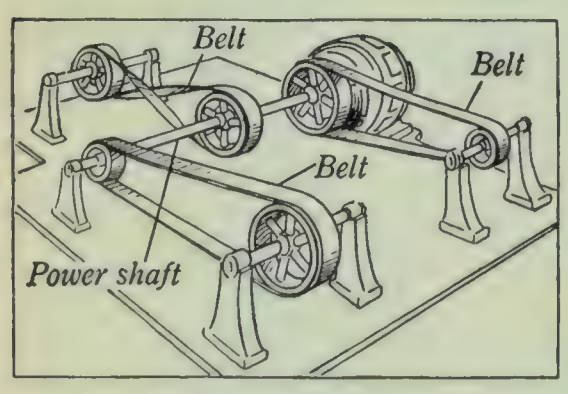


FIG. 103. Belts are used (1) to carry energy to other places where it is needed; (2) to change the direction in which pulleys rotate or turn; and (3) to make pulleys rotate slower or faster. Which of the belts in this diagram accomplishes each of these purposes?

Machines serving in more than one way. Sometimes the same machine may be used in such a way as to illustrate more than one of the six types. For example, when we swing a hatchet, we are using the handle as a lever. When we strike the blade of a hatchet into a block of wood, we are using the blade as a wedge. When we pry the blade out of the wood, we are again using the handle as a

[1] *Spiral* (spi'ral): shaped like a curl, or like the path one would make in going round and round a point while getting constantly farther away from the point.

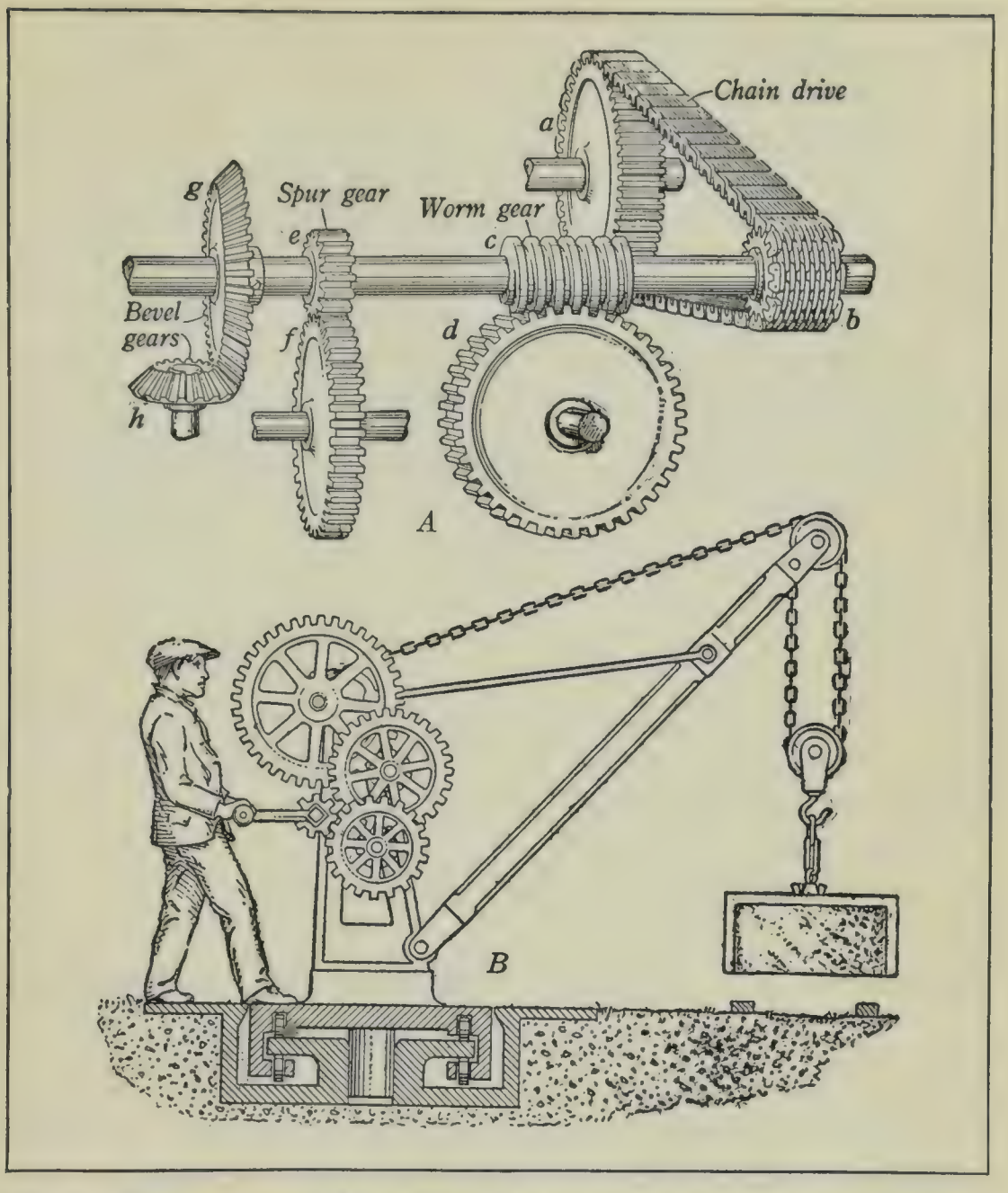


FIG. 104. Different types of gears. In *A* what does each type do that the other types cannot do? What two purposes does the chain drive serve? Do *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h* rotate in the same directions? Does *b* turn faster than *a*? Do *c*, *e*, and *g* and *d*, *f*, and *h* turn faster or slower than *b*? Which of the ways in which machines help us to do work (see page 143) does the crane illustrate? Can you find in *B* a fixed pulley, a wheel and axle, and a movable pulley? Is the crane a simple machine? Explain

lever. Can you illustrate how a garden spade may be used both as a wedge and as a lever?

Compound machines. Dozens of machines are used for a variety of purposes about the house, farm, and shop. Many of these are merely examples of the six types of simple machines which we have just discussed. Many more of them are compound machines made up of two or more simple machines, like those in Fig. 102. Belts and gears (Figs. 103 and 104) are used in many machines.

Self-test on Problem IX–B. (*Do not write in the book.*) **1.** Name the six types of simple machines, and give an example (original if you can) of each.

2. A seesaw is a simple machine and is an example of the *wheel and axle.*

3. The simple machine used in raising a flag to the top of a flagpole is the _ _(?)_ _.

4. With a fixed pulley the *force* and the resistance move in the *same direction.*

5. When the resistance is attached to a movable pulley block, the *force* is always greater than the *resistance,* and the resistance is always moved a *greater* distance than the force.

6. Stair steps are an example of _ _(?)_ _.

7. An automobile is an example of *simple* machine.

Problem IX–C · What are the Relations between Work and Efficiency and between Work and Power?

Labor-saving devices. People often speak of machines as "labor-saving devices" or "devices that save work." Although machines are frequently time-saving and force-saving, they are never "labor-saving devices" in the sense that they save work. In fact, the total amount of work put into a machine (if we take no account of friction) is always exactly equal to the total amount of work done by the machine. This is called the Principle of Work.

Since, however, there is always friction in every machine, some of the work put into the machine serves no *useful* purpose. It only wears away parts of the machine or moves parts which have become loose. Therefore the total amount of work put into a machine is always greater than the amount of *useful* work got

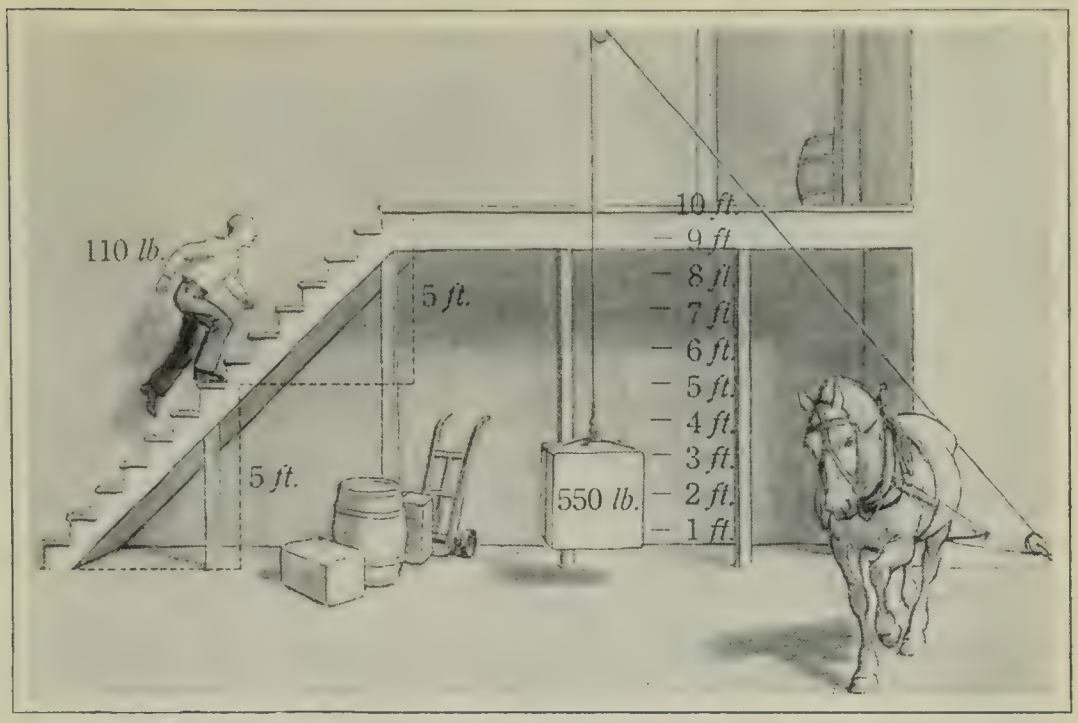


FIG. 105. If the boy lifts his weight of 110 pounds five feet in one second and the horse lifts the 550-pound box one foot in one second, each develops one horsepower. Explain

out of it. Thus, in Fig. 95, p. 147, the total amount of work put into the machines by the man in lifting the box 10 feet is $55 \times 20 = 1100$ foot-pounds. (Remember that his hands move twice as far as the box.) The useful work done upon the box in lifting it 10 feet is only $80 \times 10 = 800$ foot-pounds.

Efficiency. The efficiency of any machine is always found by dividing the useful work got out of the machine by the total amount of work put into it. For example, the efficiency of the pulley system used in raising the box in the problem we have just been considering is $800 \div 1100 = 0.727$, or 72.7 per cent. The efficiency of any machine is always expressed as a percentage. Efficiency is always less than 100 per cent. Why?

Power. If you should go upstairs from the first floor to the second, you would do the same amount of work upon yourself whether you ran up as fast as you could or walked slowly. Although the work done would be the same in both cases, the amount of *power* you would develop would be very different. Power depends upon the amount of time consumed in doing work. Power, therefore, is the rate of doing work. The faster the work is done

the more power is developed in doing it. The unit of power is the horsepower, which is 33,000 foot-pounds of work done in one minute, or 550 foot-pounds of work done in a second (Fig. 105). Thus, in Fig. 95, p. 147, if the man is able to raise the box a distance of 10 feet in 1 second he would develop 1 horsepower (usually spoken of as H.P.), because he would do 550 foot-pounds of work in 1 second, which is 1 H.P. If he required 5 seconds to lift the box, he would be doing only $1100/5 = 220$ foot-pounds of work in a second. He would therefore develop only $220/550 = 0.4$ H.P. An automobile engine of 40 H.P. can make the automobile go much faster than an engine of 25 H.P., because it can do more work upon the automobile in the same time. It has greater horsepower because its rate of doing work is greater.

Experiment 24. How many horsepower can *you* develop? Run upstairs as fast as you can while somebody times you accurately to the second. Measure the height of one step and then count the number of steps to find out how many feet you lifted yourself. With this distance and your weight, find the amount of work you did upon yourself. Then find your horsepower by dividing the work you did in one second by 550.

Self-test on Problem IX–C. 1. Less work is *sometimes* put into a machine than is got out of it.

2. If an automobile truck can deliver a ton of coal in half the time required for a horse to deliver it in a wagon, the truck develops (1) the same power as the horse; (2) slightly more power; (3) twice as much power; (4) half as much power; (5) slightly less power.

3. The *greater* the friction in a machine the *greater* is its efficiency.

4. A force of 1100 lb. moves an automobile 10 feet in 1 second. How many horsepower are developed?

5. If the total amount of work put into a machine is half the amount of useful work that is got out of it, then the efficiency of the machine is __(?)__ per cent.

Self-test on Scientific Principles. Can you give an original illustration of the principle of work?

Self-test on Understanding of Scientific Terms. Define clearly in your own words: chemical change, physical change, energy, matter, molecule, force, power, inertia, element, compound, mixture, centrifugal force, machine, density, cohesion, adhesion, and efficiency. Consult the Glossary if necessary, but restate in your own words any Glossary definitions you use. Give an illustration, original if possible, of each of these terms.

FIG. 106. Find a lever and an inclined plane in *A*; a wheel and axle and a lever in *B*; a lever and an inclined plane in *C*; three machines in *D*; two machines in *E*; name the machine which the boy is using in *F*

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Locate the types of machines in Fig. 106.

2. How many machines can you list in five minutes?

3. Which of the types of levers in Fig. 94, p. 146, is most like a ball bat? a golf club? a tennis racket?

4. How many original examples can you give of machines used as more than one type of simple machine?

5. Give as many examples as you can of compound machines which you use around your home.

6. List the simple machines which you use while eating dinner and explain how each is used. For example, "A fork is used as a wedge when it is thrust into meat."

Exercise on Scientific Method and Scientific Attitudes. Find in an encyclopedia or in a history of science the story of the struggle of some inventor in perfecting his invention. Suitable topics would include Goodyear and vulcanized rubber; McCormick and the harvester; the Wright brothers and their airplane; Westinghouse and the air brake. Show what scientific attitudes your report indicates that the inventor possessed and point out any lack of scientific attitudes on the part of others with whom the inventor associated. Indicate what steps in the scientific method (p. 9) the inventor used.

Special Reports. 1. Discuss the history of some important invention. Explain the benefits which have resulted from this invention.

2. Discuss the war machines used by the Romans and the Crusaders.

3. What is the story of Archimedes and the lever?

4. How many simple machines can you find in an automobile? in some piece of farm machinery such as a seeder, a thresher, or a harvester?

5. Give a talk before your social-science class or history class on "Machines which do the Work of Many Men."

6. Name and describe the machines which were used in and around an early pioneer home in the mountains, in the forest, or on the prairie. (Consult text-books on history.)

7. Make a list of machines which were not in existence when your father was your age; when your grandfather was your age.

Project. Write a play similar to those in Chapter XXXVIII, using as a subject some great scientific invention.

Books for Reference

DARROW, FLOYD L. Masters of Science and Invention. Harcourt, Brace and Company, New York.

KEENE, E. S. Mechanics of the Household. McGraw-Hill Book Company, New York.

MORGAN, A. P. Boys' Home Book of Science and Construction. Lothrop, Lee & Shepard Co., Boston.

WILLIAMS, A. Romance of Modern Invention. J. B. Lippincott Company, Philadelphia.

UNIT IV · *Understanding and Using Heat Energy*

PROBLEMS DISCUSSED IN THIS UNIT

Let us imagine that we have suddenly transported ourselves to a colonial or a pioneer cabin of about three hundred years ago. The single room seems small and bare, but it is bright and warm because a cheerful fire is burning in the fireplace. The warmth from the blaze is most welcome, for outside the air is cold and sharp.

Fire is one of the most precious possessions of this household. In pioneer days the live coals had to be carefully covered with ashes at night, for if possible the fire must be kept alive at all times. If the fire went out, it was not easy to kindle another. It could be done with flint and steel, or by putting in the fireplace some dry cloth and setting fire to it by firing into it a gun loaded with powder only. Or somebody might even have to go with an iron pot to the nearest neighbor's cabin for live coals.

Everybody always needed to be careful lest sparks from the fireplace should set the cabin afire. A pail of water was usually ready in case of a misfortune of this kind. If the season was dry, watch had to be kept for forest fires or prairie fires, which might sweep upon the cabin, destroying it and making the family flee for their lives.

Men have made great progress in the use and control of fire since colonial and pioneer days. Yet fire is today, as it has been since primitive man learned to use it, both a valuable friend and a dangerous enemy. In this unit we shall discuss these important problems:

What are the sources and some of the important characteristics of heat energy?
What are the relations of heat to temperature?
What do we need to know about fire and fuels?
What are some modern means of fire prevention and fire fighting?
How is heat energy transported from place to place?
What are some practical illustrations and applications of heat and temperature in and about our homes?

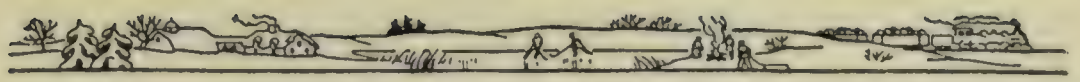
Low Temperatures Bring Winter Sports

IF YOU live in the South or the Southwest or in Southern California, you probably have had little experience with really cold weather. You probably are able to play golf, tennis, baseball, and similar games during the entire winter. You probably can swim, row, and have picnics all the year round. But if you live in Canada, New England, the Middle West, or wherever the winters are cold, you are familiar with a very different kind of winter sport. No doubt then you know the joys of skating on a smooth pond, of sliding, skiing, or tobogganing down a snowy hill, of fishing through the ice of a frozen lake, and of similar sports.

Of all the pastimes where winters are cold, however, none is more pleasant than a straw-ride party. Everything about it is fun: riding at a slow pace behind the horses, for of course automobiles would never do for a straw-ride party; burrowing down in the straw with plenty of warm blankets to tuck round you and with enough hot-water bottles or hot bricks to keep Jack Frost at a respectful distance; singing to the accompaniment of merry sleighbells; dashing along the snowy roads for an hour or so, then back for a hot supper. And what an appetite the sharp, cold air has given you!

FIG. 107. How many sports that depend on fairly high temperatures can you name? How many that depend on temperatures below freezing?

There are many scientific problems to be found in this picture. Here are two: why are the straw and the blankets warm as well as soft? why can you see the horses' breath? How many more problems can you find in the picture? Some of these you can already answer and explain, and many others you will be able to explain after you have studied this unit.



Chapter X · Relations of Heat to Temperature

Questions this Chapter Answers

What is the nature of heat?
What are the sources of heat energy?
What is the relation of expansion and compression to heat energy?
How does heating and cooling a body affect its size and its condition or state?
What is the distinction between heat and temperature?
How are heat and temperature measured?

Problem X–A · What are the Sources and Some of the Important Characteristics of Heat Energy?

Heat a form of energy. Until the beginning of the nineteenth century even the greatest scientists believed that heat was a fluid. They thought that bodies got warm when this fluid (which they called *caloric*) flowed into them and cold when it flowed out of them. They knew that bodies did not get heavier when they became warmer, or lighter when they became colder. So they thought that caloric must be a peculiar fluid which had no weight, and that therefore it could not be matter.

*In 1799 Sir Humphry Davy found that by rubbing pieces of ice together he could produce enough heat to melt the ice. Thus by transforming mechanical energy into heat he proved that heat is a form of energy and not a fluid. This experiment put an end to the caloric theory.

The sun a source of energy. The sun is the earth's most important source of heat energy. Without the sun's heat all the plants and animals on the earth would soon die. Even man, with all his scientific knowledge, could not long survive if the sun were to stop sending its vast quantities of heat energy out through space.

Chemical action as a source of heat energy. Oxidation is an especially important source of heat energy. In Chapter II we learned that when wood decays, or when wood burns, it combines

with oxygen; that is, it oxidizes. It gives off exactly the same amount of heat energy when it burns up during a few hours as when it decays during many years. When it decays, the heat is produced slowly and is not noticed. When it burns, this same amount of heat is produced so rapidly that the wood becomes incandescent. Such rapid oxidizing, or oxidation, which produces noticeable heat and light, is called combustion. Man is able to live in cold climates because he has learned to control combustion. Thus he has ready at hand a supply of heat energy whenever he may happen to need it (Fig. 107).

Fig. 108. The way in which a chemist holds a stopper while pouring from a bottle. Why is this better practice than to lay the stopper on the table?

Oxidation, especially combustion, furnishes the most important and common method, but not the only one, of transforming potential energy into heat energy.

Experiment 25. Can chemical energy be transformed into heat energy when there is no oxidation? Fill each of three beakers with cold water. Into one pour a few drops of sulfuric acid (Fig. 108). Feel the bottom of the beaker and of the other beakers. Does the temperature of the water change in any of them? Is chemical energy transformed into heat energy? Put into the second beaker a small amount of lime which has never been exposed to air or water. Quickly drop the lime into the beaker and immediately cover the beaker with the plate. Feel the bottoms of this beaker and the remaining one. What do you observe? Is chemical energy transformed into heat energy?

Exercise on scientific method (using controls). What are the controls in this experiment? Explain.

***Friction, compression, and electricity as sources of heat energy.** When you inflate a bicycle tire or an automobile tire with a hand pump or a foot pump, the bottom of the piston chamber becomes hot. Part of this heat is caused by friction. The rest is caused by compressing the air. The high temperatures inside the

earth are thought to be caused to a great extent by the compression of the materials of the earth because of gravity. Heat energy is also produced by electrical energy. Electric stoves and other electrical heating devices transform electrical energy into heat energy.

The relation of expansion to heat energy. You are probably familiar with the fact that if you hold your finger in the jet of air as it escapes from the valve of an automobile tire, the air feels cold. The reason is that the air is rapidly expanding. Whenever a body of air is allowed to expand, it becomes cooler. We should expect this to be true from the fact that a body becomes warmer when it is compressed. Thus, expansion of a gas uses heat energy.

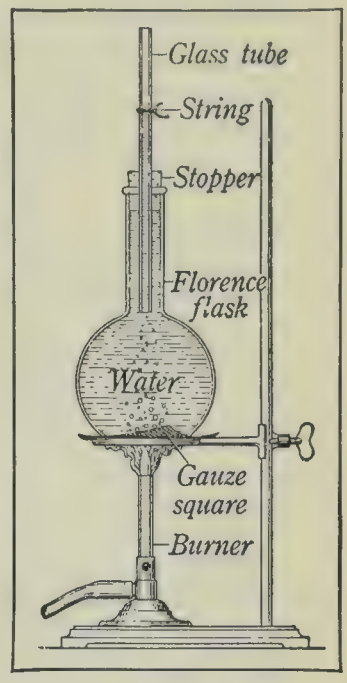


FIG. 109. Why does the milkman not fill the milk bottles entirely full of cold milk in summer?

Relation of evaporation to heat energy. You are also probably familiar with the fact that wet clothing is much colder than dry clothing, and that your face or hands become cold quickly when they are wet. The reason is that the water is evaporating. Whenever water or other liquids evaporate they become colder. Thus the evaporation of a liquid, like the expansion of a gas, uses heat energy; that is, some of the heat energy is transformed into another form of energy.

*__The effect of heat upon the size or volume of a body.__ ***Experiment 26.*** Does a solid body expand (become larger) or contract (become smaller) when it gets hotter? when it becomes colder? Secure a soft-iron bolt and a washer which will barely slip over the bolt. Heat the bolt and see whether it will still pass through the washer. Cool the bolt by dipping it into cold water. Will it pass through the washer now? Summarize the results by putting the word *expanded* or *contracted* into the blanks in the following sentence:

The solid body (the bolt) __(?)__ when it was heated and __(?)__ when it was cooled.

Experiment 27. Does a liquid body expand or contract when it gets hotter? when it becomes colder? Set up apparatus as in Fig. 109.

Fill the flask so full that when you insert the rubber stopper the water will rise a little way in the tube. Tie a string round the tube on a level with the water in the tube. Heat the water in the flask. After you have heated the flask for a few moments tie another string round the tube to indicate the water level. Pour cold water over the outside of the flask to cool it. Again note the level of water in the tube. Summarize the results by putting the word *expanded* or *contracted* in the blanks in the following:

The liquid body (the water in the flask) __(?)__ when it was heated and __(?)__ when it was cooled.

Experiment 28. Does a body of air expand or contract when it is heated? when it is cooled? Put an inflated rubber balloon or a rubber ball in a very cold place and leave it for about ten minutes. Leave another similar inflated balloon or rubber ball in the room, for use as a control. Compare the sizes of the object and its control. Then put one of the balloons or balls in a warm place long enough for it to become warm but not hot enough to burn the rubber. Again leave the other in the room for use as a control. Compare the sizes of the object and its control. Summarize the results of these two experiments by putting the word *expanded* or *contracted* in the blanks in the following sentence:

The body of air __(?)__ when it was heated and __(?)__ when it was cooled.

The effect of heat upon the state of a body. We know that matter exists in three states: solid, liquid, and gaseous. If exactly the proper conditions can be secured, a substance can be changed from a solid (as ice) to a liquid (as water) and from a liquid to a gas or vapor (as steam) by heating it. Similarly, a substance can be changed from a gas (as steam) to a liquid (as water) and from a liquid to a solid (as ice) by cooling it.

Freezing points and melting points. Certain substances, like water and metals, have each a certain temperature at which they freeze or boil. Thus water freezes or ice melts at 0° C.[1] Water boils at 100° C. Lead freezes (becomes a solid) or melts at about 330° C. Melted lead boils and becomes a vapor at 1800° C. The boiling and the freezing temperature never vary for a given substance of this kind provided the air pressure does not change. Other substances, such as lard and tar, have no definite freezing

[1] C. means measured on the scale of the centigrade thermometer.

or boiling temperatures. These substances change their state gradually as the temperature changes. Thus the warmer they are, the softer they are.

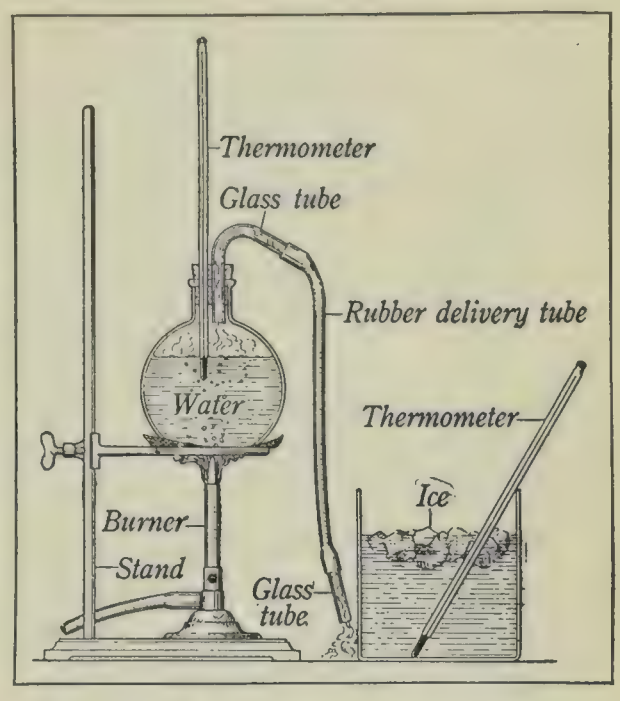


FIG. 110. How many changes of state are taking place in this diagram?

Experiment 29. Does water change temperature while it is boiling? while ice is melting in it? while steam is condensing in it? Set up apparatus as in Fig. 110. Stir ice in the beaker until the water remains at constant (unchanging) temperature. Light the burner. Note the temperature when the water begins to boil in the flask. Continue to note it while the water continues to boil. After the steam begins to come freely from the end of the tube, insert the tube in the beaker containing the ice and water. Stir with the thermometer while the ice is melting. Does the steam continue to rise through the ice water? What happens to it? Does the water in the beaker change its temperature while the ice is melting? Does it change its temperature after the ice is all melted? Make complete sentences answering the three questions asked at the beginning of this experiment.

*Summary. Sources of heat energy are the sun, chemical change (especially combustion), friction, compression, and electrical energy. Heat energy is used when there is expansion of a gas or evaporation of a liquid. Heat energy changes the size or volume of a body and may change its state. Some substances boil or freeze only at a certain temperature. Other substances change from the liquid to the solid state or from the solid to the liquid state gradually as the temperature changes.

Self-test on Problem X–A. (*Do not write in the book.*) **1.** Five sources of heat energy on the earth are __(?)__, __(?)__, __(?)__, __(?)__, and __(?)__.

2. When a tire is punctured, the *air* becomes *cooler* as it escapes.

3. The evaporation of water makes *wet* objects *warmer.*

4. When a metal ball is heated it becomes *smaller* than when it was cold.

5. A rubber ball filled with air is *slightly larger* in summer than in winter.

6. A cup nearly full of hot coffee would be somewhat *more nearly* full after the coffee had cooled.

7. An iron bar is a *good example* of a frozen metal.

Problem X–B · What are the Relations of Heat to Temperature?

Heat and temperature not the same. If you were told that the water in a swimming pool is eight feet deep, you would not know from this statement how much water is in the pool. Similarly, if you were told that the temperature of the room is 70 degrees, you would not know how much heat energy the room contained. Heat is energy. Temperature is not energy. Temperature is a measure of how hot or cold an object is. Stated in another way, temperature is a measure of how intense the heat is. Two bodies may be at the same temperature and yet contain very different quantities of heat energy. For example, a kettle of boiling water contains more heat energy and hence will melt more ice than a drop of boiling water will, because there is more of it at the same temperature. Also, a body at a lower temperature may contain more heat than one at a high temperature. For example, a kettle of warm water contains more heat energy and hence will melt more ice than will a drop of boiling water. The reason is that the greater quantity of water in the kettle more than makes up for the higher temperature of the drop.

What is cold? Cold cannot be added to a body or taken from it because cold is not energy. Cold is the absence of heat. A body becomes colder (that is, it reaches a lower temperature) only because it loses heat energy. A body becomes warmer (that is, it reaches a higher temperature) only because it gains heat energy.

Measuring temperature. When you are out walking in the spring the first friend you meet may say, "It's cool today, isn't it?" The next friend you meet is just as likely to remark, "Aren't you glad it is warm today after so much cool weather?" In the

autumn we often have what we call a cool day, when the lowest temperature may be 50° F. If we have a day with this same temperature in the middle of the winter, however, we think of it as an unusually warm day. When we speak of a cool breeze, we merely mean a current of air cooler than the air to which we have been accustomed.

These are all examples of unscientific observations and conclusions. No scientific observations of temperatures, however, were possible until about three hundred fifty years ago, when Galileo invented the first thermometer. This instrument (Fig. 111) consisted of a bulb with a long stem inverted in water. The bulb was first heated to drive out some of the air. When the bulb cooled, the air in it contracted. The greater air pressure outside then forced the water part way up in the tube.

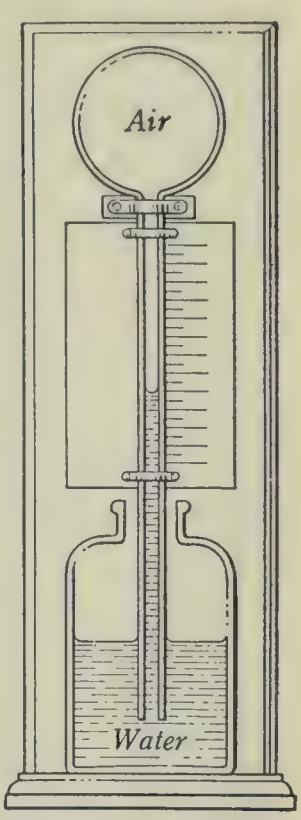


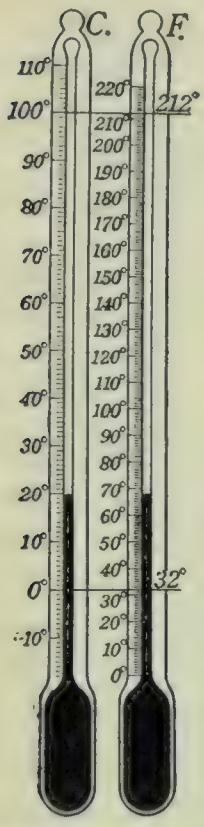
FIG. 111. Galileo's air thermometer. The water level rose in the tube when the temperature fell, and fell in the tube when the temperature rose. Explain. This thermometer was affected not only by changes in temperature but also by changes in atmospheric pressure. Explain

Experiment 30. Why are thermometers necessary for measuring temperatures? Heat water until it is comfortably warm to the touch. Fill two pans of the same size with this warm water. The water will then be at almost exactly the same temperature in both pans. Hold one hand in cold water for two minutes and hold the other hand for the same length of time in water much warmer than that in the two pans. Quickly put one hand in each pan of water. Does the water *feel* as if it were at the same temperature in both pans? Why do scientists prefer to use thermometers in measuring temperatures?

Exercise on scientific method (isolating the experimental factor). Temperature is here the experimental factor. Explain.

***Thermometers.** Ordinary thermometers are glass tubes usually containing mercury but often containing alcohol colored red or blue. Above the mercury or alcohol in the tube is a partial

vacuum. When the temperature is raised, the liquid expands toward the top of the tube. When the temperature is lowered, the liquid contracts. Alcohol and mercury are convenient substances to use in thermometers because neither freezes at ordinary temperatures. Experiment 27, p. 163, illustrates the principle of the thermometer.



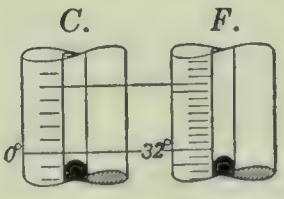


FIG. 112. Five centigrade degrees occupy the same space on a thermometer as nine Fahrenheit degrees. Therefore 1° C. = $\frac{9}{5}$° F. and 1° F. = $\frac{5}{9}$° C. Why are degrees marked in the thermometer above the boiling point and below the freezing point?

***Putting the scale on a thermometer.** The scale is marked on a thermometer by putting it first into melting snow or ice. If it is to be a centigrade thermometer, the level of the alcohol or mercury is marked 0°. If it is to be a Fahrenheit thermometer, the level is marked 32°. The thermometer is then held in steam. When the liquid in the thermometer has stopped expanding, the level is marked 100° if it is to be a centigrade thermometer and 212° if it is to be a Fahrenheit (Fig. 112). On the centigrade thermometer the space on the tube between the boiling and freezing points (that is, the boiling and freezing temperatures) of water is divided into 100 equal parts. Each of these parts represents a centigrade degree of temperature. The space on the tube between the boiling point and the freezing point on the Fahrenheit thermometer is divided into 180 equal parts. Each of these parts represents a Fahrenheit degree of temperature.

Experiment 31. Do the boiling points and the freezing points on certain thermometers agree? Place the bulbs of two thermometers first in melting snow or melting ice and then in the steam just above boiling water. Do both thermometers register exactly the same temperatures for the freezing point and for the boiling point of water? (Ordinary household thermometers will burst before they reach boiling point.)

Reading temperatures from a graph. Fig. 113 is a graph showing centigrade and Fahrenheit temperatures. This graph enables

you to change centigrade to Fahrenheit temperatures or Fahrenheit to centigrade temperatures without doing any arithmetic. To find the centigrade temperature which equals any given

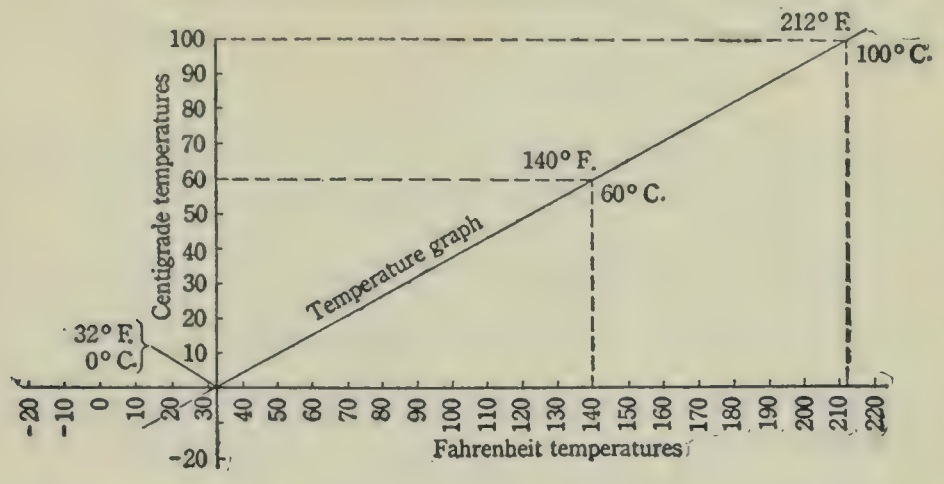


FIG. 113. A temperature graph. Can you read on the graph the Fahrenheit temperature corresponding to 20° C.? the centigrade temperature corresponding to 50° F.?

Fahrenheit temperature, say 140° F., find 140° on the Fahrenheit temperature line. Find the point directly above 140° F. on the slanting line, then find the point on the centigrade temperature line exactly opposite the point on the slanting line. This point is at 60° C.

***Measuring heat.** Heat energy is measured in calories. A calorie is the quantity of heat energy which must be put into 1 gram of water to raise its temperature 1° C.[1] Thus it would require 1 calorie to raise the temperature of 1 gram of water from 20° C. to 21° C. Also, 1 calorie would be given off by 1 gram of water when it is cooled from 21° C. to 20° C.

It requires more calories of heat energy to raise the temperature of water a degree than it does to raise the same weight of any other common substance a degree. Thus, the number of calories required to raise the temperature of 1 gram of water a degree would raise the temperature of 1 gram of glass about 5° C., 1 gram of iron about 9° C., and 1 gram of lead or gold more than 30° C.

[1] This is the definition of the small calorie. The large Calorie is the quantity of heat necessary to raise the temperature of 1 kilogram of water 1° C.

The same quantity of heat is given off when a body cools a given number of degrees as was put into the body when it was heated the same number of degrees. Thus, 1 kilogram of water gives off 1000 calories when it cools 1° C. because 1000 calories must be added to the kilogram of water in order to raise its temperature 1° C.

Self-test on Problem X–B. (*Do not write in the book.*) **1.** A hot iron bar has *the same amount* of heat energy as a colder iron bar of the same weight.

2. A drink of ice water makes one cool because it *adds cold to* the body.

3. Above the mercury or alcohol in a thermometer is a *perfect vacuum.*

4. It requires 10 *grams* of heat to raise 1 *calorie* of water 10° C.

5. Degrees are used to measure the __(?)__ of a body; __(?)__ are used to measure the heat energy that a body contains.

6. A change of temperature of 5° C. represents a change of __(?)__° F.

Self-test on Scientific Principles. 1. Can you explain how the principle of conservation of energy (see Index) applies to the materials in Problem X–A?

2. How many original examples can you think of which illustrate this principle: "In general, bodies expand when heated and contract when cooled"? Do any of the problems at the end of this chapter illustrate this principle? Explain.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why are you able to squeeze water out of damp snow when you make a snowball?

2. How many calories of heat would be necessary to raise the temperature of 10 kilograms of water from 40° C. to 50° C.?

3. How many calories of heat would be given to your hands by 1 kilogram of water if when you put your hands into the water you lowered its temperature 2° C.?

4. Why is a hot-water bottle full of hot water a better foot warmer than a hot iron of about the same weight, even though the iron may be somewhat hotter to begin with?

5. When a physician wants to determine whether or not you have a fever, why does he put a small thermometer into your mouth instead of deciding by merely putting his hand on your forehead or by asking you whether you think you have fever?

6. Arctic and antarctic explorers cannot use mercury thermometers. Explain.

7. Why is the alcohol in thermometers colored?

8. How many reasons can you state for requiring the use of centigrade thermometers?

9. What temperature centigrade is equal to 86° F.?

10. What temperature Fahrenheit is equal to 90° C.?

11. If the atmospheric pressure remained the same at all points within two hundred miles of the earth, how would the volume of a balloon change (Fig. 12, p. 24) as it ascended? Explain.

12. Should you expect telephone wires to be longer or shorter in winter than in summer? Explain.

Exercise on Scientific Method (Inventing Experiments). Would a bottle exactly full of cold milk contain a greater weight of milk than the same bottle exactly full of warm milk? Can you plan an experiment by which to get the answer to this problem? What is the experimental factor (see Glossary) in this experiment? What is the control (see Glossary)?

Exercise on Scientific Attitudes. Five opinions are given below the statement that follows. Which one of these would a trained scientist be likely to select as best? State one or more of the scientific attitudes (pp. 12 and 13) to justify your choice.

In many places, especially about Naples in Italy, many of the people believe that certain persons become cursed with the "evil eye," so that anyone whom they look at will fall sick or have other bad luck unless something special is done to break the charm.

a. The belief is silly.

b. In the cases of some people the belief is probably well founded.

c. There is very little doubt that the belief is sound.

d. It is hardly likely that there could be any sound foundation for such a belief.

e. I do not believe in the "evil eye," but I wouldn't risk having anything to do with anybody who was said to be cursed with it.

Special Reports. 1. Make diagrams of a pressure cooker and describe its operation.

2. Find what kinds of thermometers are used in very cold regions. What kinds are used in scientific work for measuring very high and very low temperatures? (Consult an encyclopedia.)

3. Describe the earliest types of thermometers. (Consult an encyclopedia or a history of science.)

4. Discuss the Réaumur thermometer. (See "To the Student," p. xv.)

Chapter XI · Securing and Using Heat Energy from Fuels

Questions this Chapter Answers

What are the conditions necessary for combustion?
What are the products of combustion?
What kinds of substances are incombustible?
How are matches made?
What are the characteristics and the relative values of common fuels?
What is fireproof construction?
How are fires extinguished?
How may greater safety be provided in case of fire?

Problem XI–A · What do we Need to Know about Fire?

Fire an important aid to man. No one knows how many thousand years ago and under what circumstances men first discovered how to use fire. There is no doubt, however, that the use of fire has been an important factor in the advance of civilization. At first primitive men probably had to use fire when and as they found it. Later they learned how to produce and control it. At first it served merely for warmth, later as a means of cooking food, and much later still as a means of melting and shaping metals. Considering the many ways in which fire proved both a help and a danger, one can understand why some primitive peoples worshiped fire. In fact there are fire worshipers in some countries even at the present time.

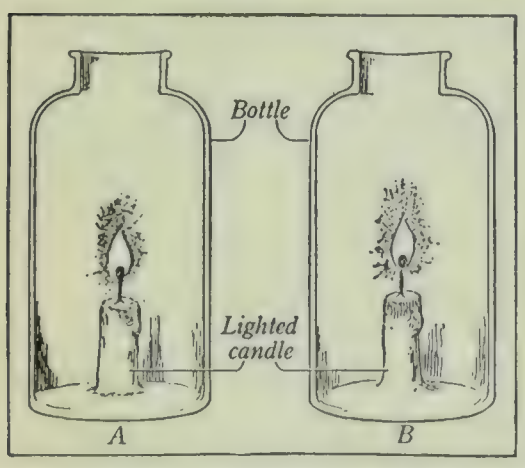


Fig. 114. Exercise on Scientific Method (Using Controls): What is the control in each part of Experiment 32?

*Conditions necessary for combustion. *Experiment 32.* Will a candle continue to burn without a fresh supply of air? Select two candles of

equal length and place one in each of two jars or wide-mouth bottles. Light both candles (Fig. 114). When both are burning, completely cover the mouth of jar *A* with a glass plate. What happens? If either candle continues to burn, extinguish it, then remove the plate from jar *A*. Fan air into both jars until you are certain that the air in both jars is the same. Light both candles again. Now place the glass plate over the top of jar *B*. What happens? Answer with a complete sentence the question asked at the beginning of this experiment.

Exercise on scientific method (using a check experiment). The second half of this experiment was a check experiment. What purpose did it serve?

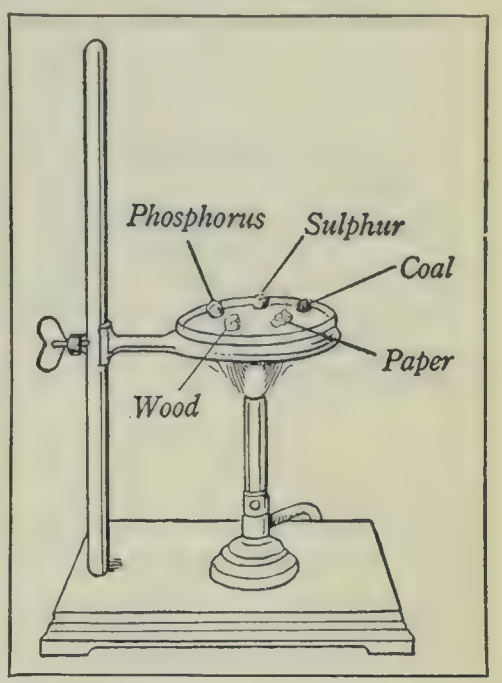


FIG. 115. This experiment and Experiment 32 together show the three conditions necessary in order to start combustion. What are these conditions?

Experiment 33. Do combustible substances begin to burn at the same temperature; that is, do fuels have the same or different kindling temperatures? Put a piece of tin on a stand (Fig. 115). Place a burner so that when it is lighted the flame will strike the middle of the piece of tin. Place on the top of the tin in a circle, at equal distances from where the flame will strike, combustible substances such as a small piece each of sulfur, red phosphorus, paper, wood, and coal. Light the flame and during five minutes watch what occurs. Describe what occurs.

Fire will not burn — that is, this kind of combustion will not take place — unless oxygen is present. We therefore pile the wood or coal loosely so that the air can pass through the fuel, bringing fresh supplies of oxygen as they are needed for combustion. If the fuel is not piled loosely, the fire goes out because not enough oxygen can reach the fire to continue combustion.

*In building a fire we begin with small, light, and dry materials, such as paper and wood kindling. We then pile the larger pieces of wood or coal loosely around or on the kindling. We know it would be useless to try to ignite [1] large pieces of fuel with a match.

[1] *Ignite* (ig nite′): to set on fire or to begin to burn.

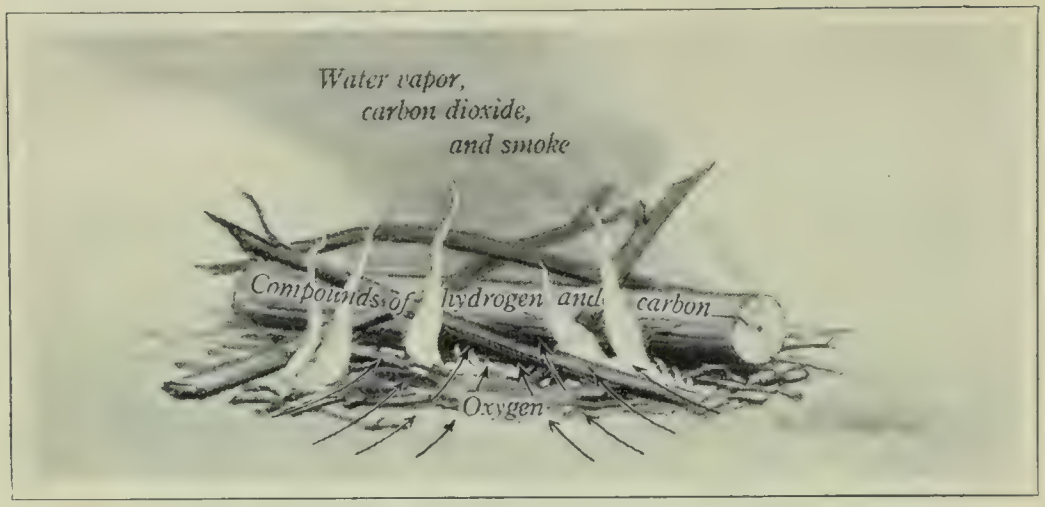


FIG. 116. Can you explain this figure?

Cold wood will not burn, neither will cold coal. The fuel must become heated before it will burn. Therefore we light the paper. The flame slowly spreads through the pile of fuel. As soon as part of it becomes hot enough to burn, the heat energy given off by this combustion heats the rest until it also is hot enough to burn.

*Every substance must be heated to a certain temperature before it will ignite. The temperature at which the substance begins to burn is called the kindling temperature, or the kindling point, of the substance. When a candle is lighted, the wick[1] is first raised to the kindling temperature. It begins to burn and to produce heat rapidly. The heat first melts some of the paraffin, then changes the liquid paraffin to a vapor. When the paraffin vapor becomes heated to its kindling point, it begins to burn. In Experiment 33 we found that some of the substances ignited readily. These substances have a low kindling temperature; that is, combustion begins when these substances are at a relatively low temperature. Loose paper is such a substance and is therefore good material with which to start fires. Hard coal has a much higher kindling temperature.

***Products of combustion.** All fuels contain compounds of hydrogen and carbon. Therefore, whenever any fuel burns, the oxygen of the air combines with the compounds of carbon and hydrogen in the fuel. Thus carbon dioxide and water (hydrogen oxide) vapor are always products of combustion (Fig. 116).

[1] *Wick*: a string or a woven strip used in a candle or an oil lamp.

Experiment 34. Can it be shown that water is formed when gas burns? Thrust a thick piece of cold, dry metal into the flame of a gas burner. After an instant remove the metal. Can you observe steam rising from its surface? Explain, keeping in mind the facts that cooking gas contains compounds of hydrogen and carbon, and that the air around it contains oxygen.

Exercise on scientific method (inventing experiments). Describe how you would proceed in order to find whether carbon dioxide as well as water is formed when a fuel such as cooking gas burns. If necessary, review Experiment 6, p. 33.

Carbon monoxide both a poison and a fuel. Sometimes when there is not enough oxygen present to burn all the carbon completely, carbon monoxide is formed instead of carbon dioxide. Carbon monoxide is a very poisonous gas. People die if for a few minutes they breathe air which contains one part of carbon monoxide for several hundred parts of oxygen and nitrogen. Carbon monoxide has no color and no odor, so that sometimes people are overcome by it without knowing it is in the air. Carbon monoxide is formed in coal and coke furnaces and is given off in the exhaust from an automobile. People should therefore be sure that their furnaces do not allow any of the products of combustion to get into the house. Also they should be careful never to start the automobile engine when the doors of the garage are closed. They should be careful, too, never to inhale cooking gas, because it contains some carbon monoxide. Carbon monoxide is itself a good fuel. It burns readily in air, forming carbon dioxide.

The smoke problem. Whenever ordinary fuel is burned, smoke is formed. This smoke consists mostly of particles of carbon which have not been burned, with sometimes also very small particles of ash. The carbon is combustible; the ashes are incombustible. If the combustion were complete, all the carbon particles would be changed into carbon dioxide. When the carbon particles are not burned and are allowed to be lost as smoke, much good fuel is wasted. Moreover, the particles of carbon fill the air as soot. It is estimated that the damage done by soot to property alone in great manufacturing cities amounts to many millions of dollars a year.

People are beginning to realize that the chimneys of homes and factories must not be allowed to pour smoke into the air. The best way to get rid of the smoke is to burn the carbon par-

ticles, or soot, before these leave the furnace. Special furnaces have been designed which supply plenty of air and mix this air so thoroughly with the combustible gases and the smoke that much more of the carbon is oxidized than is oxidized with older-type furnaces. Not only is the smoke thus practically all consumed, but more heat is obtained from the fuel.

***Incombustible substances.** You are familiar with the fact that certain substances, such as rock, most metals, asbestos, brick, and glass are not combustible; that is, they do not burn in air. Such substances are called incombustible or noncombustible substances. Incombustible substances are of two classes: (1) those which do not oxidize — that is, combine with oxygen — readily; and (2) those which are already completely oxidized. Iron is a substance of the first class, because, although it burns readily in oxygen, it oxidizes slowly in air (see Experiment 5, p. 31). Carbon dioxide and water (hydrogen oxide) are substances of the second class, because the carbon of the carbon dioxide and the hydrogen of the water are completely oxidized.

***Summary.** Substances that will burn, such as fuels, are combustible substances. Those that will not burn are incombustible substances. Incombustible substances are either oxides or substances that will not readily combine with oxygen. Fuels always contain compounds of hydrogen and carbon. Hence water and carbon dioxide are always produced when these compounds burn in air. Fuels will burn only when there is oxygen present and when they have been heated to their kindling temperatures.

Matches a recent invention. The first true friction match was invented in 1827 by an Englishman, John Walker. By about 1834 matches were in general use, having taken the place of flint, steel, and the tinderbox (Fig. 117). Even today, however, not all the civilized world uses the friction match. In Chosen (Korea), for example, a very early type of match, which is merely a wooden splint tipped with sulfur, is still in use. This match will light only when the sulfur tip is touched with a live coal.

***How does a friction match light?** One type of common friction match is made by first dipping the ends of small sticks into melted paraffin. The ends with the paraffin are then dipped into a paste made of (1) a compound of phosphorus; (2) some oxidiz-

ing substance, such as manganese dioxide or potassium chlorate; and (3) glue. When the head of the match is rubbed against any rough substance, the heat caused by the friction raises the phosphorus compound to its kindling point. The heat from the burning phosphorus compound raises the paraffin to its kindling point. The heat from the burning paraffin in turn raises the wood to its kindling point. Although glass is incombustible, sometimes powdered glass is added with the glue to increase the friction. The oxidizing material supplies oxygen to increase the combustion. The glue causes the various chemicals to adhere together, and at the same time it protects the phosphorus compound from the oxygen in the air, which otherwise would slowly oxidize it.

FIG. 117. A tinderbox of colonial times, provided with flint and steel and containing tinder and sulfur-tipped matches. **Project:** To make a fire with tinder, flint, and steel. Make the tinder by charring linen. Do this by igniting the linen in a dish and then covering the dish to keep out the air. Ignite the tinder with sparks produced by striking the edge of the flint with steel. Blow on the ignited tinder until it is all glowing and then use it to ignite small dry shavings

The safety match. Friction matches are liable to be ignited, that is, set on fire, by accident. In some places, therefore, safety matches are required by law. These matches contain some of the necessary substances on the head of the match. The rest are in a thin layer on the side of the box. If the head of the match is rubbed against a rough surface, the head is rubbed off without lighting the match. But if it is rubbed against the substances on the side of the matchbox, the friction sets the match on fire in much the same way that the friction match is ignited.

Self-test on Problem XI–A. (*Do not write in the book.*) 1. Iron rust is an example of an incombustible substance, because it is already completely __(?)__.

2. Two products which are always formed when fuels burn are __(?)__ and __(?)__.

3. Smoke consists largely of unburned __(?)__.

4. Fuel *should be warmed* before it will burn.

5. The temperature at which a fuel takes fire is called its __(?)__.

6. Fire cannot be made to burn unless there is present (1) nitrogen; (2) carbon dioxide; (3) oxygen; (4) smoke; (5) argon.

7. A match is provided with a substance which ignites at a low __(?)__ and with another substance which furnishes __(?)__ to help the burning.

Problem XI–B · What are the Relative Values of Various Kinds of Fuels?

***Solid, liquid, and gaseous fuels.** Familiar solid fuels are coal, coke, wood, and charcoal. Familiar liquid fuels are petroleum (crude oil), the products of petroleum (chiefly gasoline), and alcohol. Familiar gaseous fuels are natural gas, coal gas, and, to a small extent, acetylene.

*The chief sources of heat energy for cooking and heating in the United States and Canada are coal, gas, wood, electricity, fuel oil, and kerosene (Fig. 118). Although gasoline is used comparatively little in homes for heating and cooking, it must be classed with the important fuels because it is used in automobile engines and other gas engines. About twice as much of the heat used for manufacturing and industry is secured from coal as from gas, but about twice as much of the heat used for homes is secured from gas as from coal.

Wood as a fuel. Wood was probably the only fuel known to primitive men. It is still used as the chief fuel for homes in parts of the United States, Canada, and those other parts of the world in which it is sufficiently plentiful. More than four fifths of the wood used in homes is burned on farms, and almost all the rest is used in cities of less than thirty thousand population. Coal, coal gas and natural gas, electricity, gasoline, kerosene, and crude oil are rapidly taking the place of wood as a fuel.

Charcoal as a fuel. If wood is heated where the air cannot reach it, it does not burn or oxidize. The hydrogen, oxygen, and nitrogen of the wood combine with some of the carbon to form simple compounds. These compounds pass off, leaving charcoal, which is mostly carbon with some mineral matter. Charcoal is a

good fuel, burning without flame and with little smoke and leaving the mineral matter in the form of a white ash. In burning,

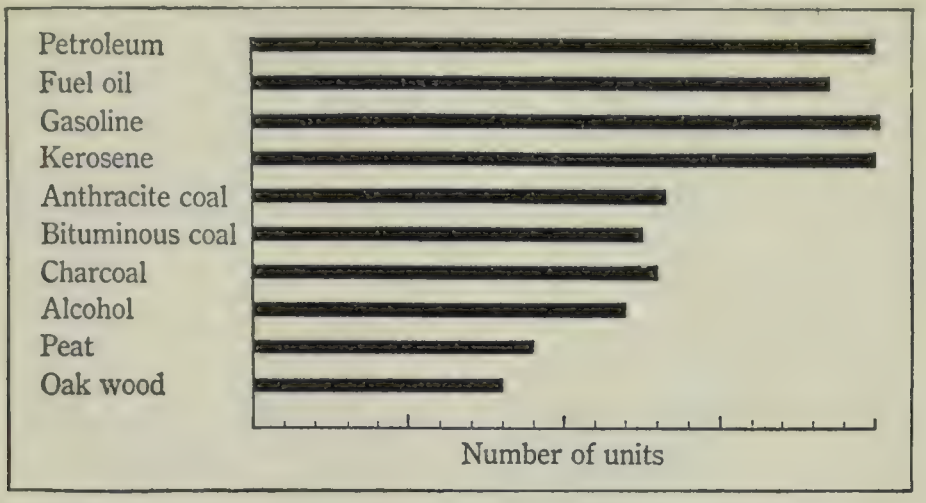


FIG. 118. Graph showing relative heating values of equal weights of common fuels. These values vary somewhat with different samples of the fuels. The graph shows that one ton of petroleum furnishes 2½ times as many calories as one ton of oak wood. What are some other factors to be considered in deciding which is the most desirable fuel?

however, charcoal is likely to produce considerable quantities of carbon monoxide. It is therefore dangerous to burn charcoal in open burners indoors.

***Coal as a fuel.** Coal is composed mostly of carbon. It also contains hydrogen, oxygen, and other substances, including ash.

There are various kinds of coal which differ in composition and heating values. The most common kinds are anthracite, or hard coal, and bituminous, or soft coal. Anthracite coal is a popular fuel for use in homes because it has little coal dust, because it burns slowly and therefore does not require frequent stoking,[1] and because it burns with scarcely any smoke. It is, however, much more expensive than soft coal, and hence finds little use in industry.

Bituminous coal has several disadvantages: it crumbles readily into coal dust and hence is very dirty; it burns rapidly and consequently demands frequent stoking; and when it burns it produces much soot and smoke. In spite of these disadvantages, however, more than 80 per cent of all coal used is soft coal, because it

[1] *Stoke:* to supply with fuel.

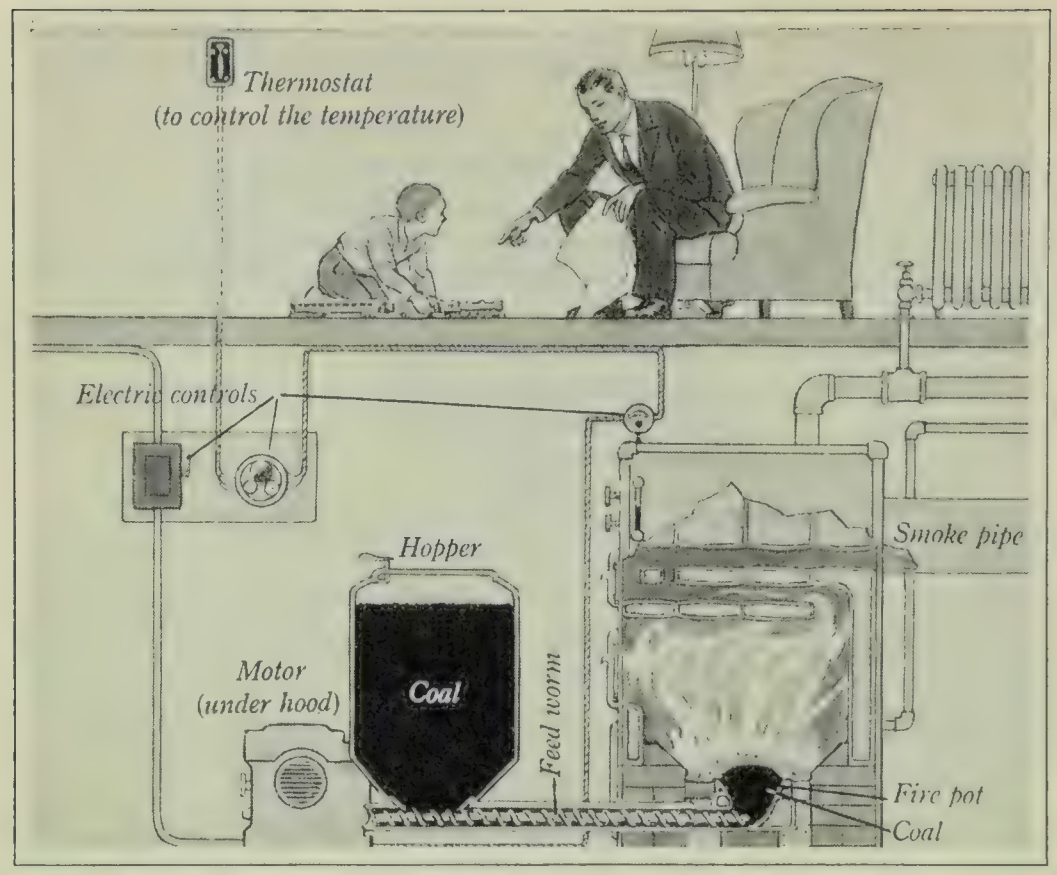


FIG. 119. An automatic coal stoker. An electric motor turns the feed worm, which forces the coal into the fire pot from below. The motor also turns a fan, which forces air through a pipe leading to the bottom of the fire. The thermostat shuts off the motor when the room has reached the desired temperature. **Special Report:** The operation of a thermostat. (Consult a textbook of physics)

is so much cheaper than hard coal. Moreover, the disadvantage of frequent stoking has been partly removed through the invention of automatic[1] stokers for use in homes (Fig. 119). Also a way has recently been found for treating soft coal with oil, which keeps the dust from flying and from being tracked about. As a result of these inventions, soft coal is gaining in favor as a fuel for home heating.

Coke as a fuel. Coke is made from soft coal. The coal is heated in coke ovens from which nearly all the air is shut out so that the coal will not be consumed. The gaseous compounds in the coal are driven off, leaving the coke. This is a hard gray solid with practically no dust. It is not easy to set on fire, but once

[1] *Automatic* (aw to mat'ik): self-acting.

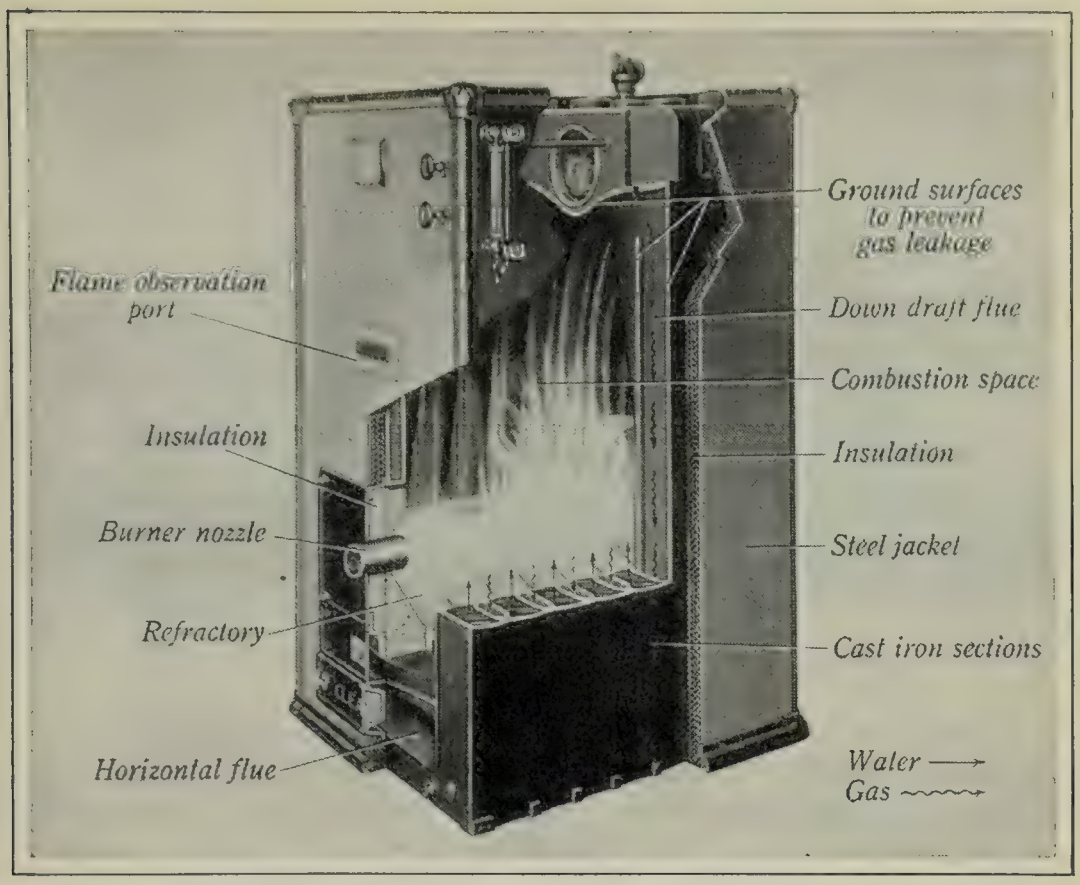


FIG. 120. An oil-burning hot-water furnace. Why are the hot gases from the combustion space made to pass downward between the hot-water pipes before being allowed to pass out of the chimney?

ignited it burns with little flame and much heat. Millions of tons of coke are made in the United States every year for use in reducing iron ore to iron. Coke is a by-product[1] from the manufacture of cooking gas.

Oil as a fuel. Fuel oil is a product obtained from petroleum or crude oil. It is used widely on ships, and its use for home heating is rapidly increasing. It is expensive as compared with soft coal, but is very clean and convenient. A modern automatic oil furnace (Fig. 120) requires little attention from the beginning until the end of winter.

Natural gas. Natural gas is cheap and is much superior to artificial coal gas. It is used in homes for cooking and heating and to some extent in such industries as the making of steel, pottery, brick, and glass. It is obtained chiefly from oil wells.

[1] *By-product:* a product secured in the process of manufacturing some more important product.

Coal gas. In parts of the country where natural gas cannot be obtained cheaply, artificial gas is made from soft coal (Fig. 121).

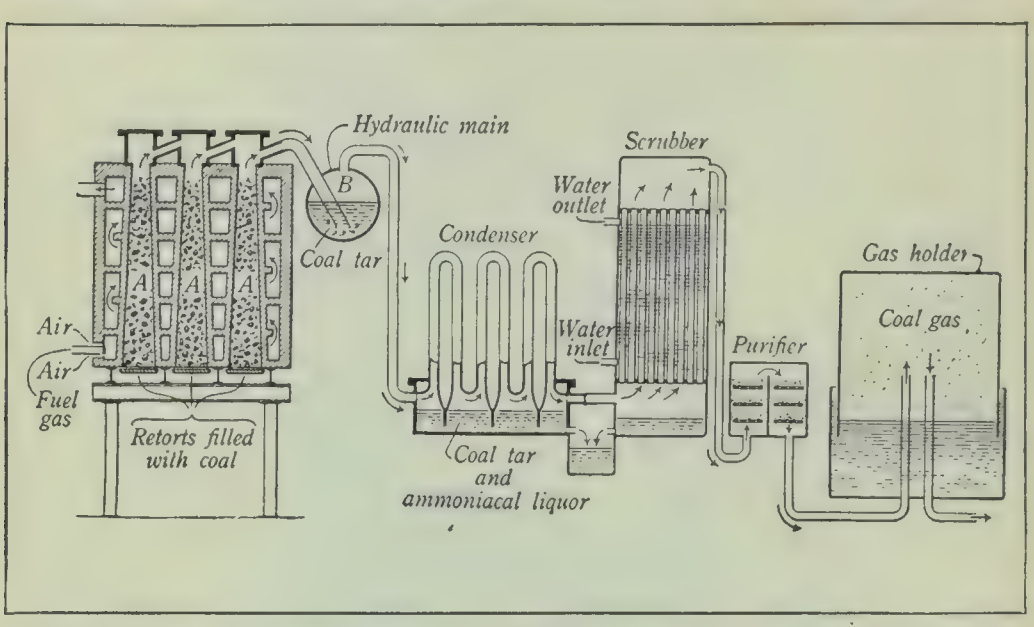
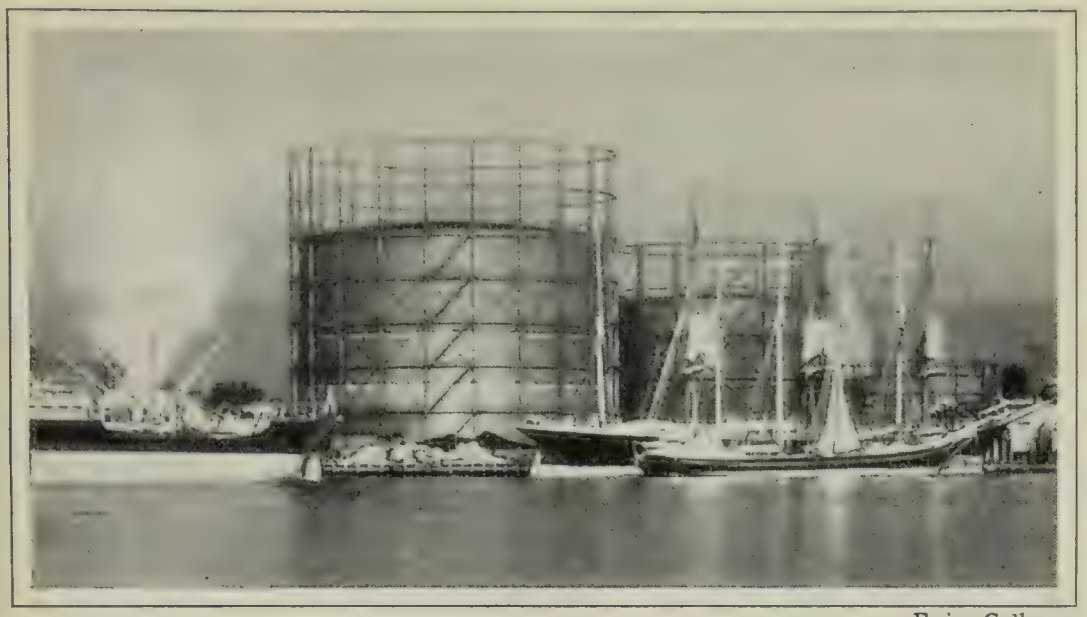


FIG. 121. Diagram of a coal-gas plant. With the aid of the text and the diagram, can you explain the manufacture of coal gas? **Special Report:** The manufacture and uses of water-gas

The coal is heated for several hours in special chambers called retorts. No air is allowed to enter the retorts. Gaseous compounds containing carbon and hydrogen are driven off by the heat. These compounds are allowed to bubble through water. This cools them and condenses some into solids and liquids called coal tar. The gas passes through long vertical coils of pipe called the condenser. Here the rest of the coal tar condenses. Liquid containing ammonia collects on the surface of this coal tar. The gas then passes through a tall tower called the scrubber. This scrubber is filled with loose pebbles or coke, over which water is sprayed. In passing through the water the gas is made cooler, and any impurities in it are dissolved in the water and removed. The gas now passes into the purifier, which is a series of boxes fitted with frames covered loosely with lime or iron oxide or both. These compounds remove the remaining impurities from the gas. The purified gas now enters the gas-storage tanks (Fig. 122), from which it is distributed to homes, factories, and business houses.



Ewing Galloway

FIG. 122. A gas storage tank at Oakland, California. What causes the top of the tank to rise and fall at times?

A ton of good gas coal produces about 10,000 cubic feet of gas, and also valuable by-products, which include 1200 pounds of coke, 120 pounds of tar, and 20 gallons of ammonia liquid. Valuable products made from the tar are used for preserving timber, for protecting paint, and also in making tarred paper and black varnishes. When coal tar is distilled it releases substances from which medicines, explosives, perfumes, and dyes are made. The ammonia liquid is made into fertilizer.

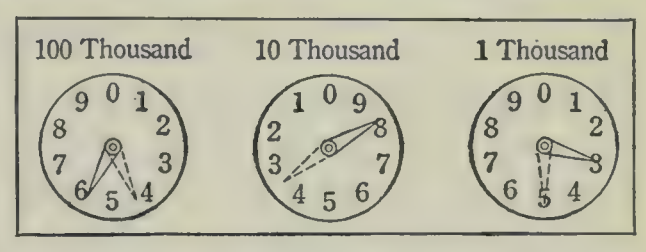


FIG. 123. The dials of a gas meter. The hand moves entirely around the dial in registering the number of cubic feet of gas printed above the dial. Thus, when the hand has passed from 0 to 1 on the left-hand dial, 10,000 cubic feet, not 100,000 cubic feet, of gas have been used. The dotted positions of the hands show where the hands were when the meter was last read. The reading was then 43,500 cubic feet. The present reading is 58,300 cubic feet. Therefore 14,800 cubic feet of gas have been burned during the time between the two readings. At $1 per thousand cubic feet, what would the bill be? Make a diagram showing where the hands of the dials would be if the reading were 87,100 cubic feet

The gas meter. Where natural gas is very plentiful, people are sometimes charged a certain fixed sum, or "flat rate," and they are allowed to use as much gas as they wish.

Usually, however, the amount of gas burned is measured by a meter. The users of the gas are then charged a certain sum for each thousand cubic feet of the gas which they burn. Fig. 123 shows the dials of a gas meter.

Alcohol as a fuel. The use of alcohol as a fuel is likely to increase. Alcohol is a compound of carbon, hydrogen, and oxygen. Wood alcohol is made from wood. Grain alcohol is made by the action of yeast plants upon grains and potatoes. Alcohol burns without smoke and with a very hot, almost colorless, flame.

Self-test on Problem XI–B. (*Do not write in the book.*) **1.** The most common fuel used in homes is ___(?)___.

2. The most common fuel used in industry is ___(?)___.

3. Coal is composed mostly of *oxygen.*

4. Compare hard and soft coal. (See "To the Student," p. xvi.)

5. Artificial gas is made from *anthracite* coal.

6. Coke is made from *wood,* and charcoal is made from *soft coal.*

Problem XI–C · What are Some Modern Means of Fire Prevention and Fire Fighting?

***Fire is both a friend and an enemy.** Without the help and use of fire our modern civilization would not be possible. Yet when fire is not properly controlled, it becomes a terrible enemy. Many millions of dollars are lost every year through the destruction of homes and buildings by fires (Fig. 124) and through forest fires.

Fireproof construction in buildings. Many homes are set on fire by sparks which ignite the wooden shingles of the roof (Fig. 124, *D*). As a means of removing this danger, asphalt and asbestos shingles which cannot be set on fire are rapidly taking the place of wooden shingles. As a further means of preventing the starting and spreading of fires in homes and also in public buildings, the spaces between the walls, above the ceilings, and under the roofs are filled with mineral wool, which is incombustible.

***Ways of extinguishing fires.** Fire will continue to burn only when it has a constant supply of oxygen and when the fuel is kept at its kindling temperature. Fires can therefore be extin-

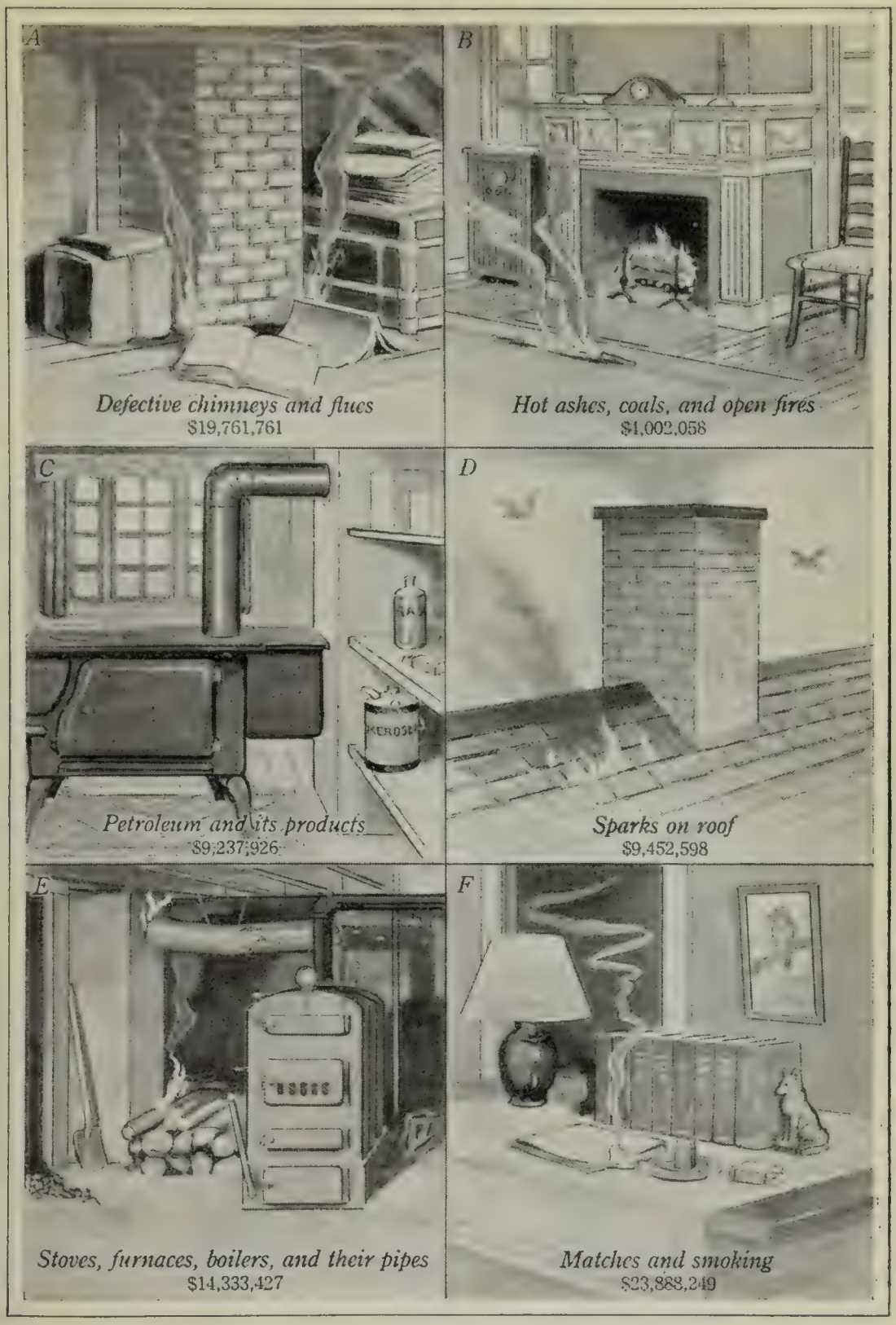


FIG. 124. For many years the yearly fire losses in homes and buildings in the United States have totaled over three hundred million dollars. The losses pictured here could all have been prevented. How many causes of fire which are not shown here can you name?

guished (put out) (1) by preventing oxygen from getting to the burning material, or (2) by cooling the burning material below its kindling temperature, or (3) by doing both. Wrapping a rug or blanket round a person whose clothing is on fire is usually the easiest and quickest way to extinguish the flame. Thus the combustion stops because the supply of oxygen is cut off.

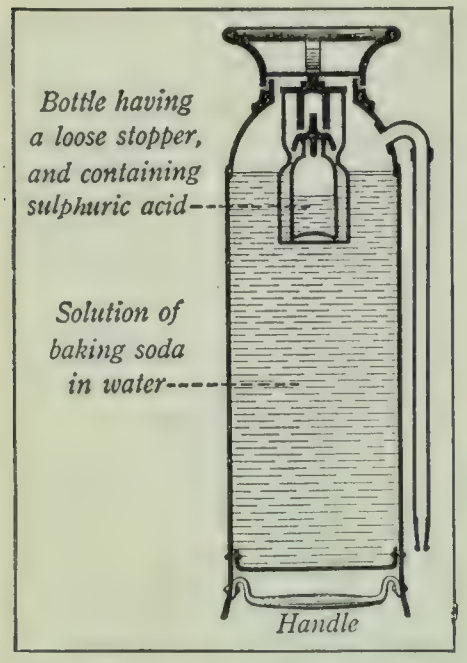


FIG. 125. The soda-acid fire extinguisher. The water and carbon dioxide from this extinguisher should be discharged at the base of the fire. Explain

Water as a fire extinguisher. Water is valuable as a fire extinguisher mainly because it cools the fuel below its kindling temperature, but it is also valuable because it keeps oxygen away from the burning fuel. It does not serve to put out oil fires, however, because the oil floats on the top of the water, where it continues to burn and may spread if the water in flowing away carries it to other combustible materials. Much of the damage attributed to fire is often due to damage done by water.

***Chemical fire extinguishers.** Chemical fire extinguishers find a valuable use in fire engines, public buildings, and homes. The commonest type of fire extinguisher (Fig. 125) puts out the fire with water and carbon dioxide (Experiment 6, p. 33). When the extinguisher is grasped by the handle, it is turned upside down. The cork falls out of the little bottle of sulfuric acid. The acid reacts at once with the soda solution, forming carbon dioxide. The pressure of the carbon dioxide forces the carbon dioxide and water violently out of the hose. The water cools the fuel, and the water and the carbon dioxide together act like a blanket round the fire, keeping oxygen away.

In another type of fire extinguisher a small metal cylinder is filled with liquid carbon tetrachloride. The liquid is forced out of the cylinder with a piston. When the liquid strikes the fire, it

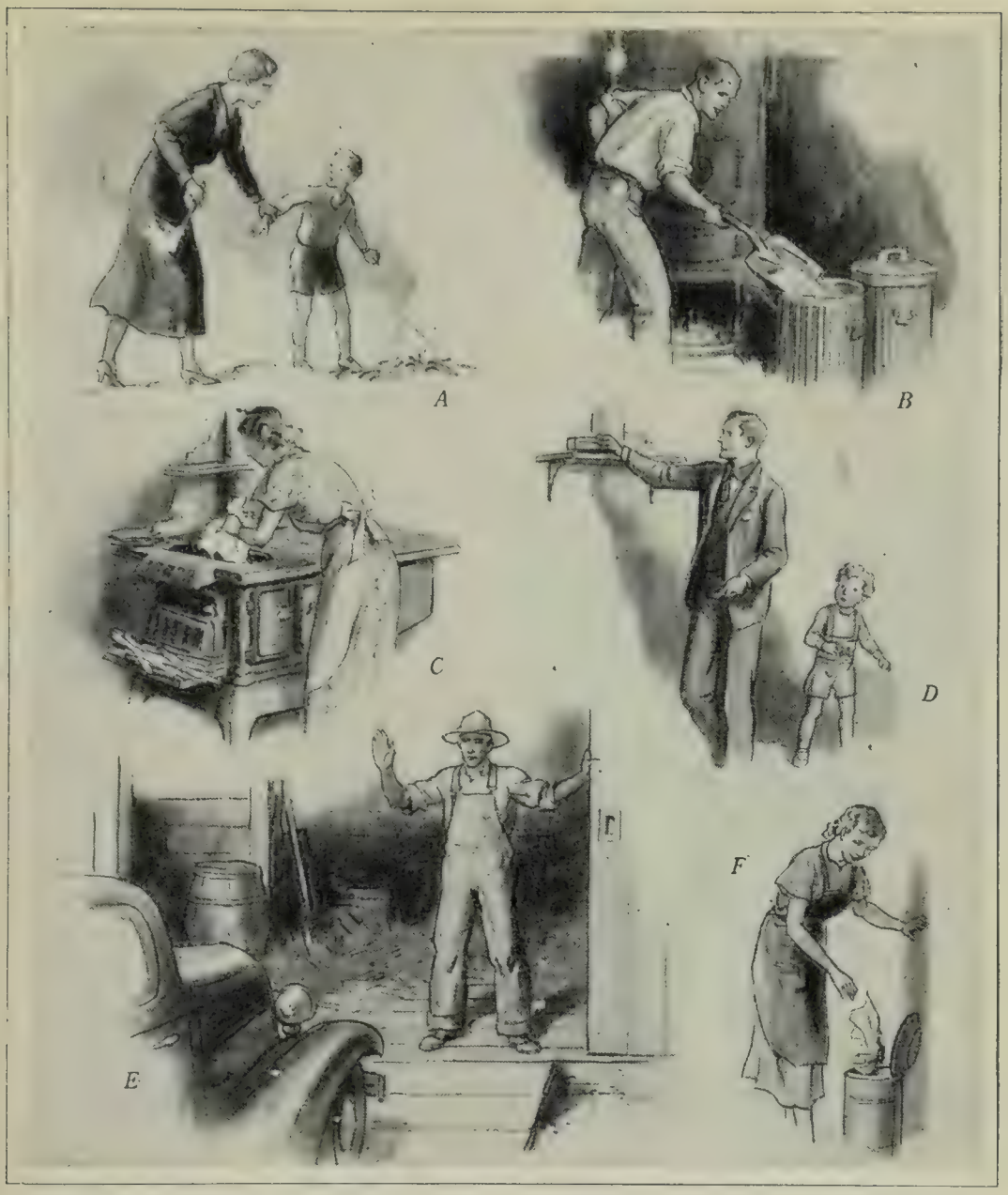


FIG. 126. Preventing fires and injury from fire. *A*, do not allow children to play with fire or to play too near an open fire. *B*, put ashes into metal drums; putting ashes into wooden barrels or boxes is dangerous. Why? *C*, start fires with paper and kindling; do not use kerosene or gasoline. Why? *D*, keep matches on a high shelf where children cannot reach them; do not let children play with matches. *E*, it is not safe to use a barn for a garage. Why? *F*, oiled cleaning cloths should be kept in metal cans; they sometimes take fire by oxidation from the air and so must not be left in closets. **Special Reports:** What are the cause and the nature of spontaneous combustion in the home, in garages, in coal piles, and in sawdust piles? What are the cause and the nature of dust explosions in flour mills and in coal mines? (Consult a textbook of chemistry)

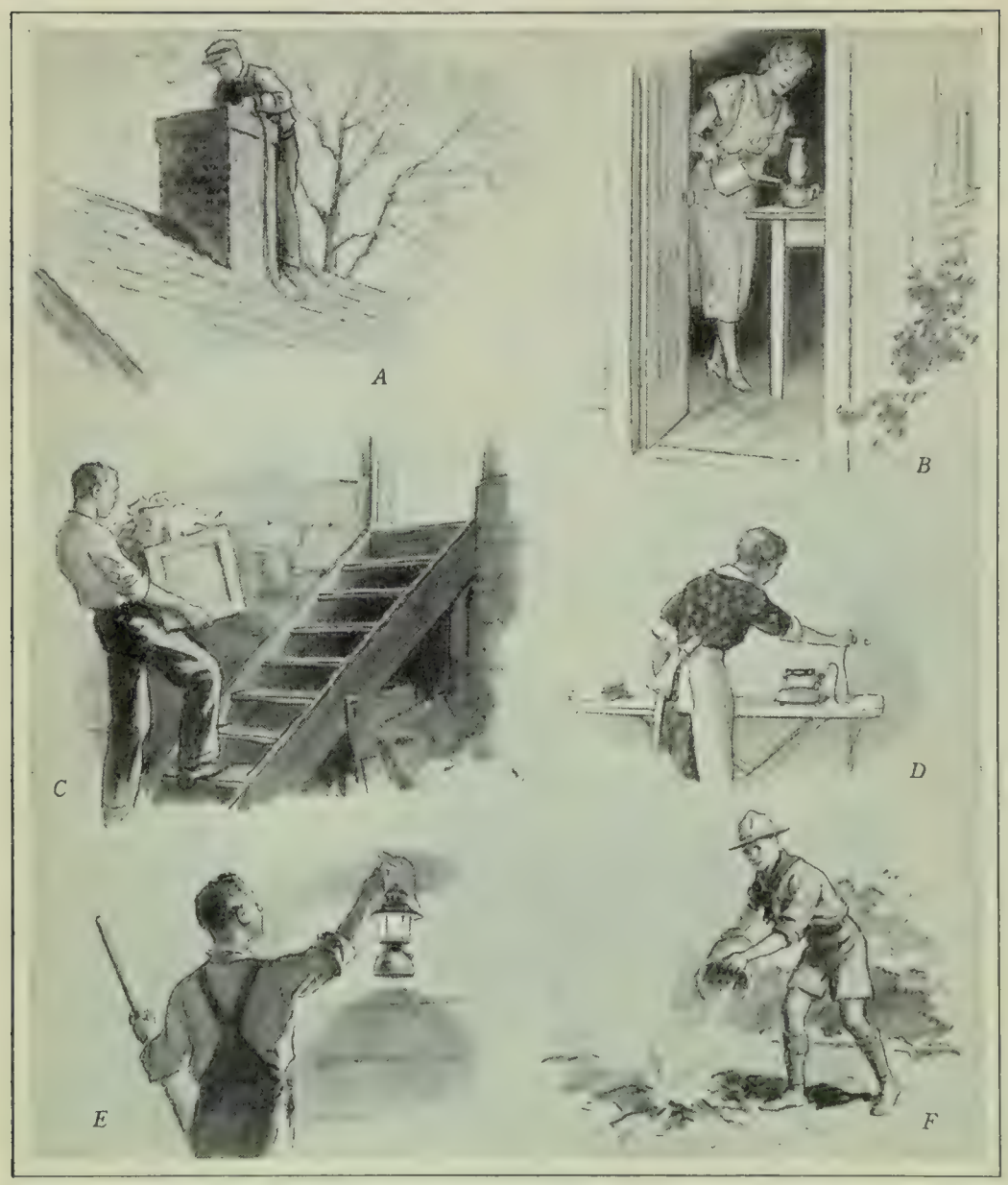



FIG. 127. *A*, clean chimneys and smoke pipes once a year. Why? *B*, fill gasoline and kerosene lamps by daylight in a well-ventilated room where there is no fire. Why? *C*, remove waste paper and other combustible materials from your basement and attic. *D*, turn off your electric devices before you leave them. *E*, place lanterns and lamps where they cannot easily be knocked over. *F*, be sure your fire is out before you leave it

immediately evaporates. The vapor is dense and incombustible and forms a blanket which shuts out the oxygen from the fire. This type of extinguisher is claimed to be most effective of all for fighting fires caused by defective[1] electric wiring.

[1] *Defective* (de fek'tiv): having defects; not normal, correct, or perfect.

Still another type of fire extinguisher makes thick-walled bubbles of carbon dioxide when the solution in it is thrown on a burning surface. This layer of thick foam forms a blanket which shuts out the oxygen. It is claimed that this extinguisher is the best yet devised for fighting oil and gasoline fires.

Providing for safety in case of fire. Schools and public buildings should be built with more than one safe way of getting out of each room in case of fire. Stairs should lead to the street, to an alley, or to an open court, and they should be enclosed with fireproof[1] materials. All doors should open outward. Fire extinguishers should be placed where they can easily be reached. Children should have frequent fire drills in school in order to learn how to *walk* quietly to safety in case the building should take fire.

Most fires can be prevented. It is well to know how to fight fires, but it is equally important to remember that most fires can be prevented. Figs. 126 and 127 suggest ways of preventing fires.

Self-test on Problem XI–C. (*Do not write in the book.*) **1.** Water puts out fire in two ways: (1) by lowering the __(?)__ of the fuel and (2) by preventing the fire from getting fresh supplies of __(?)__.

2. Which of the three ways of extinguishing fires is chiefly illustrated by putting sand on a fire?

3. Two substances which when released from fire extinguishers put out the fire are __(?)__ and __(?)__.

4. Fireproof construction consists of putting a *combustible* substance in place of *incombustible* substances ordinarily used.

5. Schoolroom doors should open *inward*, so that in case of fire the *firemen* can easily *enter* the building.

6. State the two conditions necessary in order that a fire may continue to burn after the fuel has been ignited.

7. State at least eight ways of preventing fires.

Self-test on Scientific Principles. 1. Can you explain how the burning of various kinds of fuel illustrates the principle of conservation of energy (see Index)?

2. Whenever any kind of fuel burns, most of it disappears. Can you explain how this fact is in accordance with the principle of conservation of matter (see Index)?

[1] *Fireproof* (fire'proof): made so that fire cannot get through; protecting against heat from fire.

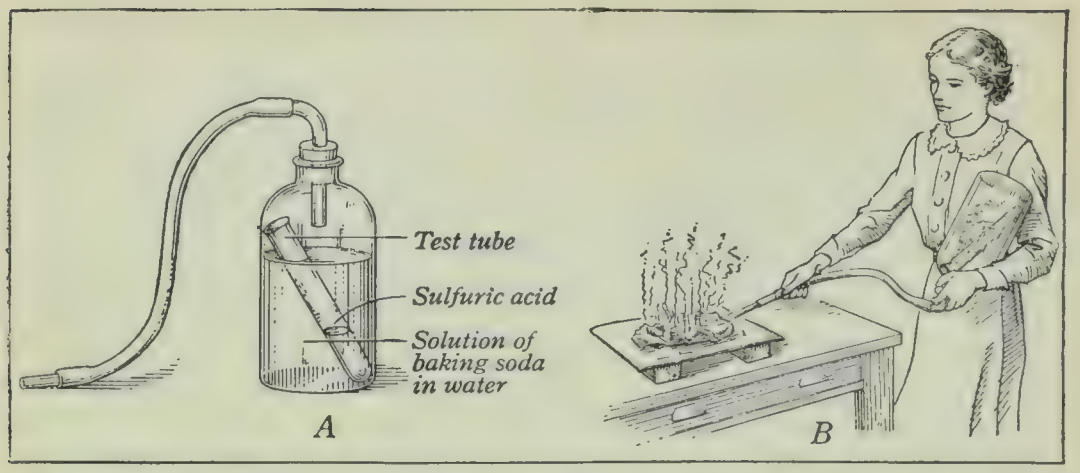


FIG. 128. *A*, a classroom model of a soda-acid fire extinguisher; *B*, using the model extinguisher. Would vinegar serve instead of ammonia in the "Caution"? Why?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is a stove or a furnace grate well supplied with openings?

2. Why does the flame creep slowly along a match instead of covering the whole match as soon as it is lighted?

3. How many incombustible substances can you list?

Projects. 1. To make some charcoal. Fill the bowl of a clay pipe with small pieces of wood tightly packed. Moisten some plaster of Paris to make a thick paste. Spread this paste over the top of the bowl so as to make an airtight cover. When the plaster is thoroughly dry, heat the bowl of the pipe in a gas flame. See whether you can light the gases which escape from the end of the pipestem. When the gases are no longer given off, remove the pipe from the flame. Break off the plaster-of-Paris covering of the bowl. In what ways is the charcoal which you have made like the wood from which it was made? In what ways does it seem to be different? Make a small fire of the charcoal to see whether it is a good fuel.

2. To make a fire extinguisher. Place a small test tube in a bottle (Fig. 128, *A*). Using a funnel, fill the test tube about a fourth full of sulfuric acid. Be careful not to spill any of the acid on your hands, your clothing, or the table. Close the bottle *tightly* with a one-hole rubber stopper equipped with a tube as in the figure. Using the funnel again, fill the bottle about two-thirds full of water in which you have first dissolved as much baking soda as possible. Build a small fire in the sink or out of doors. Hold the cork *tightly* with one hand while you turn the bottle upside down. With the other hand direct the end of the tube at the fire

(Fig. 128, *B*). Do you get better results when you direct the carbon dioxide and water at the top of the fire or at the bottom of it? Explain. [CAUTION: *The carbon dioxide may be produced fast enough when the bottle is inverted to force out the cork even though you hold it tightly. Should any liquid strike your clothing, sponge the spots at once with dilute ammonia, then sponge again with water to remove extra ammonia.*]

3. To practice with a fire extinguisher until you can put out a fire quickly and certainly. Build a good-sized fire in the yard. When it is burning vigorously, run from the fire to the place where the extinguisher is kept, secure the extinguisher, and extinguish the fire. Have somebody note how long it took you from the time you first started for the extinguisher until the fire was entirely out. Start the fire a second time and try again, to see whether you cannot cut down the time in extinguishing the fire. Write down in the form of brief notes the facts learned from this experiment which you think would help in case you needed to extinguish a real fire. The extinguisher will need to be charged again.

Special Reports. 1. Charcoal has a number of uses other than as a fuel. How many can you discover and describe?

2. Describe how acetylene is made and the uses of an acetylene torch or of an oxyacetylene torch.

3. Describe a modern fire engine and its action. You will probably need to review the force pump (p. 51) in order to explain how the fire engine throws a steady stream of water on the fire.

4. Describe the sprinkler system of fire extinguisher.

5. Explore your own home to see whether there are any places where a fire might be liable to start. Make a similar survey of your neighborhood.

6. Discuss fire worship. (Consult an encyclopedia under the topics "Fire worship" and "Zoroaster.")

7. Discuss the history of fire making. (Consult an encyclopedia or books on science and invention, as C. Piercy's *Stories of Useful Inventions* (The Bobbs-Merrill Company, Indianapolis) and O. T. Mason's *The Origins of Inventions* (Charles Scribner's Sons, New York).)

Books for Reference

GREENWOOD, E. Prometheus. Harper & Brothers, New York.
JAMESON, H. The Flame Fiend. Allyn and Bacon, Boston.
MOFFETT, C. Careers of Danger and Daring. D. Appleton-Century Company, Inc., New York.

Chapter XII · How Heat Energy is Distributed

Questions this Chapter Answers

How is heat energy transferred from place to place by radiation, convection, and conduction?

What are conductors and insulators of heat?

How is convection related to winds, natural ventilation, and furnace drafts?

How are the three methods of transferring heat related to refrigeration, hot-water heating, the vacuum bottle, the making of artificial ice and ice cream, and the cooling system of an automobile?

How is knowledge of heat energy applied in our clothing and in home heating?

Problem XII–A · How is Heat Energy Transported from Place to Place?

Transferring heat from place to place. When our hands are cold we know several ways of warming them. If we are out of doors we may put them in our pockets to prevent them from losing their heat, we may rub them together to heat them by friction, we may blow our warm breath upon them, or we may exercise our arms and hands in various ways to make the blood circulate more rapidly.

*If we are indoors we may hold our hands in front of the fireplace or electric heater, over the hot-air register or radiator, or against some warm object which is not too warm for comfort. Thus we use the three ways in which heat energy is transferred from one place to another, namely, *radiation*, *convection*, and *conduction*.

***Radiation.** When heat energy radiates from a hot body it travels in straight lines from the hot body. It is able to pass in waves through a vacuum with a speed of about 186,000 miles per second.

*All the heat which comes to us from the sun travels by radiation. During the night and the winter the earth radiates away much of the heat which it receives by radiation from the sun dur-

FIG. 129. Cooking two hams by radiation from burning coke. An electric motor keeps the meat constantly turning. **Special Report:** A Dutch oven, or reflector cooker. (Consult an encyclopedia or a big dictionary)

ing the day and the summer. If the earth did not do this, it would gradually become hotter and hotter until nothing could live upon it.

Experiment 35. In what directions does heat radiate from a hot body? Heat a metal object, such as a very large iron nail or the end of an iron poker. When it is red-hot, hold it above and very close to a block of paraffin (do not let it touch the paraffin). Does the heat travel downward from the hot iron to the paraffin? Again heat the iron and hold it close beside the paraffin. Does the heat travel horizontally from the hot body? Repeat, holding the iron just below the paraffin. Does the heat travel upward from the hot body?

Radiant, or radiated, heat waves pass through the millions of miles of almost perfect vacuum between the sun and the earth without heating the space at all. When radiant heat strikes matter, however, it raises the temperature of the matter (Fig. 129). Scientists explain this fact by saying that the radiant heat makes the molecules move faster. There are some substances, however, such as air and window glass, which are almost transparent[1] to radiant heat; that is, they stop and absorb only a small part of the waves which radiate through them. Thus the ground may be warmer than the air above it, and objects in the sunlight inside a room are warmer than the window glass through which the sun's rays pass.

[1] *Transparent* (trans par'ent): allowing sunshine to pass through.

Good radiators and good reflectors of heat. Rough surfaces absorb radiant heat better than smooth and polished surfaces. Also, smooth and polished surfaces reflect radiant heat better than rough surfaces do. Thus the reflectors of electric heaters are made of smooth, polished metal so as to reflect rather than absorb the radiant heat energy. Objects with rough surfaces radiate their heat away faster than do objects with smooth surfaces. Thus the surfaces of hot-water radiators or steam radiators are made rough rather than smooth and polished. Dark-colored objects absorb radiant heat faster than light-colored objects do. Thus soot or ashes on snow will absorb the sun's heat and so will cause the snow to melt more rapidly under them than it is melting around them.

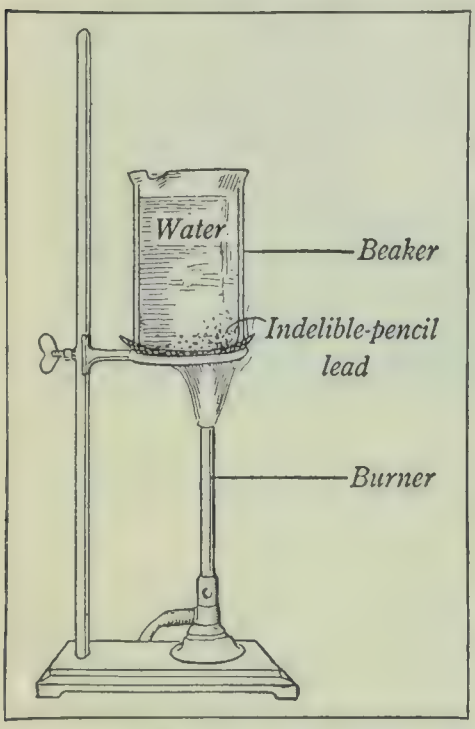


FIG. 130. What is the reason for adding the sawdust or the indelible-pencil lead?

Convection. *Experiment 36.* How does heat travel from one place to another by convection? Put some fine wet sawdust or some small bits of lead from an indelible pencil into a beaker of water so that some of the sawdust or the pencil lead is at the bottom of the beaker (Fig. 130). Light a burner under one edge of the beaker. As the water becomes heated do the bits of sawdust or pencil lead move in straight lines or in curving lines?

*Heat travels by convection in currents. When air or water becomes heated it expands and becomes less dense; that is, it weighs less per cubic foot than the colder air or water round it. The warm air or water is then forced upward for the same reason that a bubble or cork which is released beneath the surface of water is pushed up to the surface — because it is less dense than the water round it. Convection is the cause of all winds and ocean currents.

Conduction. You are familiar with the fact that when one end of an iron poker is held in the fire, the heat energy travels along the poker to the hand. This is an example of conduction of heat energy.

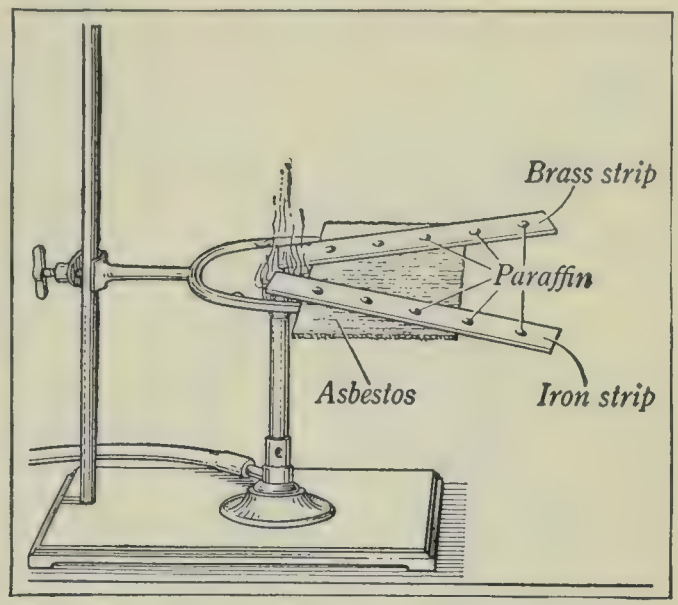


FIG. 131. The asbestos mat is a good heat insulator; that is, it does not conduct heat readily. Why is it used here?

Scientists explain how the heat is conducted along the poker in this way: The iron in the fire has its temperature raised; that is, the speed with which its molecules vibrate[1] has been increased. These faster-moving molecules hit against the molecules next to them in the poker, making them also vibrate faster; these in turn strike against molecules farther away, causing them to vibrate faster; and so on. Thus in conduction heat energy travels from molecule to molecule.

Experiment 37. Does heat energy travel by conduction with equal speed through two different metals? Put a row of small pieces of paraffin equally spaced about an inch apart on strips of two metals (for example, iron and brass) of the same size and shape, about an inch wide and six or eight inches long. Place the two strips on an asbestos mat across a ring support, with the flame adjusted below them so that the blue flame strikes each strip equally (Fig. 131). Light the burner and observe what happens. Answer with a complete sentence the question asked at the beginning of this experiment.

Conductors and insulators. *Experiment 38.* Is water a good conductor of heat? Fill a test tube with water. Dry the outside thoroughly, then hold the tube in the flame, as in Fig. 132, until the water boils above the flame. Make a complete sentence that answers the question at the beginning of this experiment, giving a reason for your answer.

[1] *Vibrate* (vi'brate): to move to and fro, as the wings of a buzzing bee. A house vibrates when a heavy truck goes by. *Vibration* (vi bra'shun): the act of vibrating.

Some substances are good conductors of heat; others are not. Substances that are good conductors are poor insulators. Substances that are poor conductors are good insulators. The metals are better conductors of heat than other substances are. Thus wooden handles are put on metal coffeepots, so that the heat energy will not be conducted too rapidly to the hand. Also, we wear gloves while driving or working out of doors in cold weather because the gloves are poor heat conductors and good insulators and hence will not rapidly conduct the heat energy out of our hands. Solids, in general, conduct heat better than liquids do, and liquids conduct heat better than do gases. Silver is the best heat conductor known.

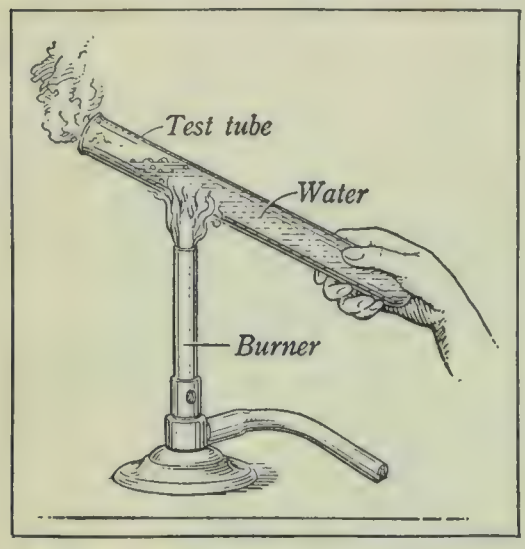


FIG. 132. Would it be comfortable to hold the tube if the hand and the burner were to exchange places? Explain

*Summary of important differences. Heat energy travels by radiation in waves without the help of matter. It travels by radiation through a vacuum. It travels by convection and conduction only by means of matter. Radiant heat energy travels at enormous speed in straight lines and in any one direction as readily as in any other. Heat energy carried by conduction or convection travels slowly compared with radiant heat and often may travel in curving routes. Convection currents are set in motion by gravity. Convection takes place only in liquids and gases. Conduction takes place mostly in solids, very little in liquids, and almost not at all in gases. Heat is conducted when rapidly moving molecules strike against other molecules which are moving more slowly. Heat is carried by convection when an enormous number of rapidly moving molecules travel together. It will help you to get a better idea of convection if you will observe or think of a moving swarm of insects. Each has its own speed and direction within the swarm, but all are moving in the same general direction.

Self-test on Organization of Facts. Under the name of each of the three methods of transferring heat energy, list its characteristics in such a way as to contrast it with the other methods, thus:

Radiation	Convection	Conduction
1. Travels through a vacuum.	1. Travels in matter.	1. Travels in matter.
2. Travels in straight lines.	2. Travels in curving lines.	2. Travels in any direction.
3. __(?)__	3. __(?)__	3. __(?)__
4. __(?)__	4. __(?)__	4. __(?)__
Etc.	Etc.	Etc.

Self-test on Problem XII–A. (*Do not write in the book.*) **1.** Heat is transferred from one place to another by __(?)__, __(?)__, and __(?)__.

2. Heat travels by *convection* in straight lines.

3. The floor below a radiator becomes warm by *convection.*

4. The ceiling above a radiator becomes heated chiefly by *radiation.*

5. Heat passes readily through a vacuum by *conduction.*

6. When a person puts his hands in warm water, the hands are heated by *conduction.*

7. Tea will keep warm for a *longer* time in a bright metal teapot than in a rusty one.

8. The temperature inside a black automobile is likely to be *higher* than the temperature in a light-colored one standing beside it.

Problem XII–B · What are Some Practical Illustrations and Applications of Convection and Conduction?

***Uses of winds.** For many centuries men have been using the kinetic energy of convection currents in the air (the wind) to drive boats with sails. Primitive tribes used air currents to help drive their log canoes, and later the simplest sailing boats made use of the same source of energy. Windmills and kites have been made in the play and recreation of children as long as civilization has been making records. Even as late as the beginning of the nineteenth century practically all ocean commerce depended on the wind. Much of the commerce of the world is still carried in sailing ships. For centuries, too, the kinetic energy of wind has

been used to drive windmills for pumping water and for grinding grain. Windmills are sometimes used to generate electric current.

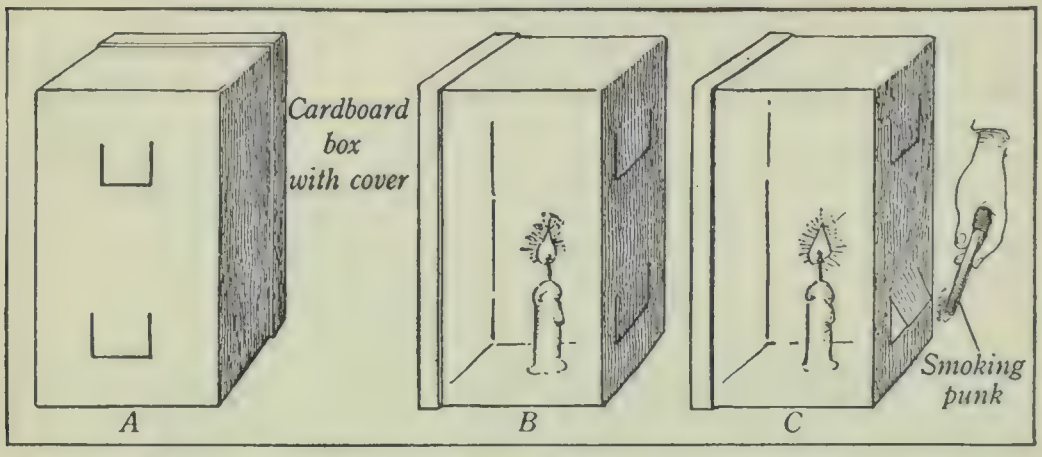


FIG. 133. A ventilation model. Special Report: The electric window-fan ventilator

What causes winds? Winds are convection currents. The surface of the earth heats unequally, (1) because the sun's rays strike some surfaces more directly than others and consequently heat them faster, (2) because some surfaces are smoother than others, and (3) because some substances heat faster than others. The air heats faster above warmer areas than it does above colder areas. As the air heats it expands and becomes less dense, thus forming a partial vacuum. The greater pressure of the denser air over the colder areas then forces colder air toward the partial vacuum over the warmer areas, causing winds, and forcing upward the air currents above the warmer areas.

***Natural ventilation.** Ventilation provides a free circulation of air in houses and buildings. Primitive men were not concerned with ventilation. Outdoor life provided all the fresh air that was needed. When men learned to build closed houses and to heat them in various ways, they gained in comfort but sometimes lost in health because of poor ventilation. People are now giving much more attention to securing the proper ventilation of their homes.

Ventilation is an application of convection. An experiment will show how a room should be ventilated:

Experiment 39. Is a better circulation of air through a bedroom secured when the window is opened at the bottom, at the top, or at both the bottom and the top? A cardboard box will here represent a bedroom.

Since usually there are windows on only one side of a bedroom, cut two flaps in one side of the box (Fig. 133, *A*) to represent the top and bottom of a window. Stand the box on one end and stand a lighted candle in the box. Note the brightness of the flame. Close the two flaps which you have cut in the side of the box and put the cover on the box with the candle inside (Fig. 133, *B*). After about two minutes carefully open the lower flap. Is the candle burning more or less brightly than it did before the box was closed? Close the flap again. Light a stick of punk, incense, or a piece of rope, and when it is giving off a heavy smoke open the lower flap (the bottom of the window) and hold the smoking punk or incense just at the opening but not inside the opening in the box (Fig. 133 *C*). Do the air currents as indicated by the smoke enter the box readily when only the lower flap (the bottom of the window) is open? Close the lower flap and open the upper one (the top of the window). Hold the smoking punk just at the upper opening. Do the air currents as indicated by the smoke enter the box readily when only the upper flap (the top of the window) is open? Open both flaps (the top and the bottom of the window) and hold the smoking punk just at each opening in turn. Do the air currents now enter one opening, or both openings, or neither opening? If you are not sure, repeat each part of the experiment until you are sure. Is the candle flame more or less bright when both openings are open than when one or both are closed? Make a complete statement which answers the question asked at the beginning of the experiment. Give a reason for your answer.

*The action of the candle in Experiment 39 is explained thus: When the candle is lighted, the air immediately above it in the box becomes heated and consequently expands. When it expands, some of it overflows from the box. Since some air escapes from the box, a partial vacuum is formed above the candle; that is, the warm air above the candle is less dense than the air surrounding the box. The greater pressure of the denser cold air outside the box forces or pushes air into the partial vacuum above the flame, causing currents to flow upward through the box.

*Proper ventilation supplies our homes with constantly moving air which is free from unpleasant odors, which has an indoor temperature of from 65° F. to 70° F., and which has enough moisture to be healthful. If sufficient fresh air is constantly being admitted from out of doors, the rooms are likely, in general, to be healthful.

***How proper ventilation is secured.** The proper use of windows in ventilating a room is shown in Fig. 134. Strong drafts may be prevented in two ways: (1) by attaching a slanting board inside the window at the bottom to direct the air currents upward as they enter the room, or (2) by fitting into the open space at the bottom of the window a frame over which cloth has been stretched.

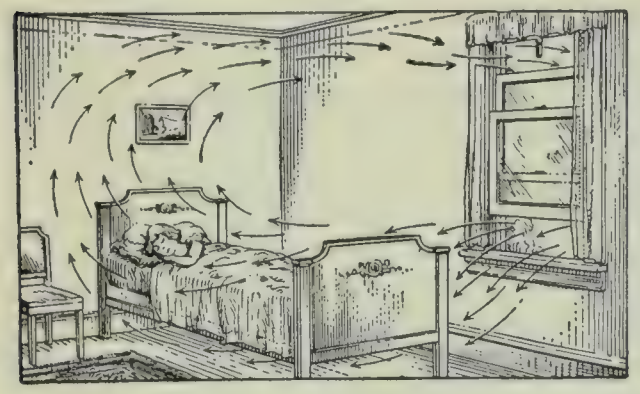


FIG. 134. Can you explain why the air circulates as the arrows indicate?

Chimneys. We are likely to think that the chief and perhaps the only purpose of a chimney is to carry off the products of combustion. This is not true. Removing the waste products of burning is only one function of the chimney. Its chief purpose is to furnish a draft. A chimney is therefore a device to increase convection. A familiar experience in fire making will make this statement clear. Sometimes when the fire in the fireplace, the stove, or the furnace is first started, it burns slowly and smokes. The smoke comes out into the house instead of going up the chimney. The reason for this is that convection currents have not yet been started up the chimney. After the air in the chimney becomes warmed, however,

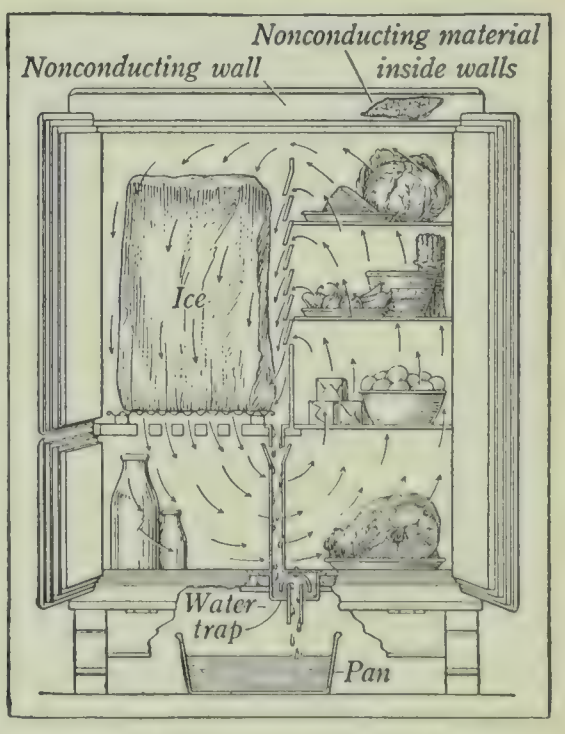


FIG. 135. An ice refrigerator. If it were not for the water trap the cold air would fall out with the water from the melted ice. Explain. What would occur if the ice were put in the bottom of the refrigerator?

the smoking ceases and the fire burns vigorously. Sometimes it is necessary to burn some paper in the chimney before the fire is started in the stove or furnace, in order to heat the air and thus cause convection currents to start. Factory chimneys are built very tall so as to increase the amount of convection by increasing the difference between the pressure of the warm column of air inside the chimney and the pressure of the colder air outside the chimney.

FIG. 136. Packing an ice-cream pudding in solid carbon dioxide. The carbon dioxide (the white material) is cut with the band saw into pieces of the proper size. Is "dry ice" a suitable name for solid carbon dioxide? Justify your answer

Refrigeration with ice. The refrigerator is an application of both conduction and convection. Whenever one body is touched by another, the warmer always gives up heat energy to the colder by conduction. Thus, when ice is put into a refrigerator (Fig. 135) it takes some heat out of the shelf upon which it rests and more out of the air surrounding the ice. When the air gives up heat to the ice, it becomes cooler and contracts. It therefore becomes heavier than the same volume of warm air in the other parts of the refrigerator. Consequently it is pulled down by gravity. As it falls it pushes up the warm air in the food compartments, making convection currents. The heat energy which the ice absorbs melts the ice. Nonconducting or heat-insulating materials are used in the walls. These greatly reduce the conduction into the refrigerator from the outside air.

Refrigeration with "dry ice." Very recently solid carbon dioxide ("dry ice") has begun to make its appearance as a substitute for ice in certain types of refrigeration. Gaseous carbon dioxide

is first condensed into a liquid. The liquid carbon dioxide is allowed to evaporate very rapidly. The evaporation makes it so cold that it freezes and looks like snow. It is then compressed and cut into blocks of convenient size to be packed around perishable[1] foods for transportation (Fig. 136). Frozen carbon dioxide does not melt into a liquid as ice melts into water. It evaporates directly into gaseous carbon dioxide without passing through the liquid state. The carbon dioxide gas which is thus formed is colder than ice; in fact, the solid carbon dioxide is 141 degrees colder than ice, or — 109° F.

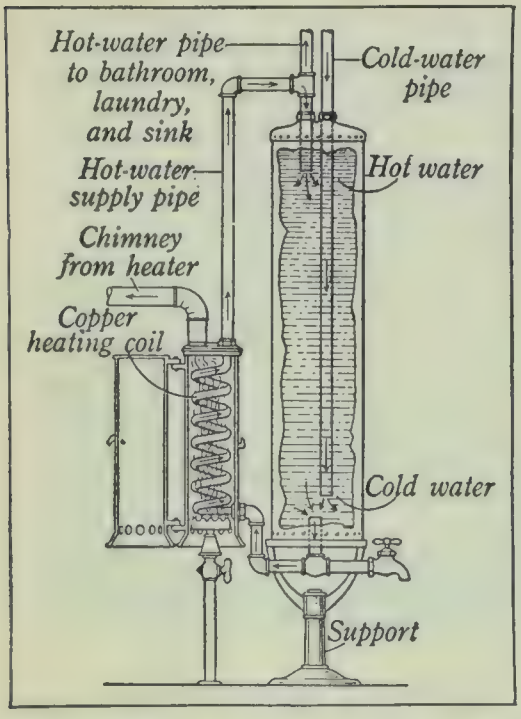


FIG. 137. Water heater and boiler. Explain why the products of combustion escape through the chimney of the heater. Why is not cold water admitted to the top of the tank? Why is the heating coil spiral instead of straight?

Solid carbon dioxide now costs much more per pound than ice. But one pound of solid carbon dioxide can do as much refrigerating as fifteen pounds of ice. At the same time it is more convenient and desirable for refrigerating perishable foods which are shipped long distances. Solid carbon dioxide is not suitable for use in household refrigerators. It is probable, however, that in the near future special refrigerators will be designed to use solid carbon dioxide instead of ice.

The hot-water heater. Nearly every home has some means of heating considerable quantities of water. Sometimes the water is heated by causing it to circulate[2] through coils of pipe installed in the firebox of the furnace. Often the source of heat is a gas water heater (Fig. 137). In every case heat energy is first con-

[1] *Perishable* (per'ish a bl): liable to decay or to be destroyed quickly.

[2] *Circulate* (sur'ku late): to move in currents from one point back to the same point. *Circulation* (sur ku la'shun): the act of circulating.

ducted through the coils. As the water absorbs this heat energy it expands and becomes less dense than the colder water below the heating coil. Convection currents are therefore set up by the greater pressure of the cold water. Sometimes the boiler is covered with asbestos. Asbestos is a good insulator, that is, a poor conductor of heat energy.

Self-test on Problem XII–B. (*Do not write in the book.*) **1.** Natural ventilation is made possible by *conduction.*

2. Ventilation and other currents in air or in water are caused by unequal *pressures* due to unequal *heating.*

3. Can you explain the action of the refrigerator (Fig. 135) by selecting the proper word or phrase from each pair in the following statements? When the air gives heat to the ice, it becomes *warmer* *cooler* and contracts. It therefore becomes *heavier* *lighter* than the same volume of warm air in the other parts of the refrigerator. It is then *pushed up* *pulled down* by gravity; and as it falls it pushes up the warm air in the food compartments, making convection currents.

4. Solid carbon dioxide changes to *liquid* carbon dioxide when the temperature is raised.

5. The circulation of water in a hot-water heater is due to *radiation.*

Problem XII–C · What are Some Further Practical Applications of our Knowledge of Heat and Temperature?

***Artificial ice.** Fig. 138 shows how artificial ice is made. When the ammonia gas is compressed, it becomes hot. The hot ammonia gas is made to pass through pipes round which cold water circulates. The cold water absorbs the heat from the ammonia gas by conduction. When the compressed ammonia gas becomes cool enough it condenses into a liquid, just as water vapor condenses into rain when it is cooled sufficiently. The liquid ammonia is allowed to pass through the valve into coils which pass through tanks of brine.[1] In these coils it evaporates rapidly, becoming cooled just as water becomes colder when it evaporates. The ammonia gas becomes still colder when it expands in the coils. The very cold ammonia gas absorbs heat from the brine by conduction, making the brine colder than the freezing temperature

[1] *Brine:* a strong solution of salt in water.

of pure water. Huge cans the size and shape of manufactured ice cakes are filled with pure water and immersed in the cold brine.

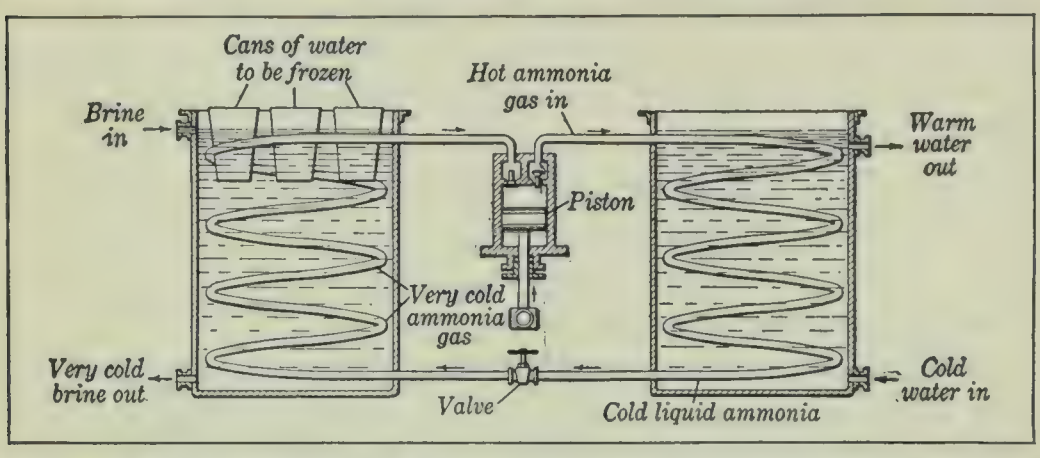


FIG. 138. Making artificial ice. Why is the outside of pipes through which very cold brine circulates often covered with frost?

The water in the cans freezes into cakes in from one to two days. In cold-storage plants, brine which has been cooled in the same way as that just described is pumped through coils in the cold-storage rooms, where it absorbs heat from the air.

Electric refrigerators. Several of the modern electric refrigerators, or iceless refrigerators, are small cold-storage and ice-making plants combined. A considerable variety of freezing substances are used in these machines instead of ammonia, but in each the process is essentially the same as that used in the manufacture of artificial ice (Fig. 139).

Freezing ice cream. Mechanical refrigerators furnish an easy and convenient way of making ice cream. The ice-cream freezer, however, is still in wide use for this purpose. Ice and coarse salt are packed around the can of the freezer. The ice alone could not cool the cream enough to freeze it. But the salt dissolves on the wet surface of the ice and causes it to melt rapidly, forming a solution of salt in water. Salt water does not freeze at 0° C., or 32° F. In fact, a saturated solution of salt does not freeze until it is cooled to — 20° C. Therefore the salt solution formed by dissolving the ice with salt is much colder than the freezing temperature of water, because (1) some of the heat energy is taken from the ice in dissolving the salt and (2) much more heat energy is used in melting the ice. The cold salt-water solution absorbs

heat conducted through the can from the cream. The tub of the freezer is usually made of wood, which is a poor conductor of

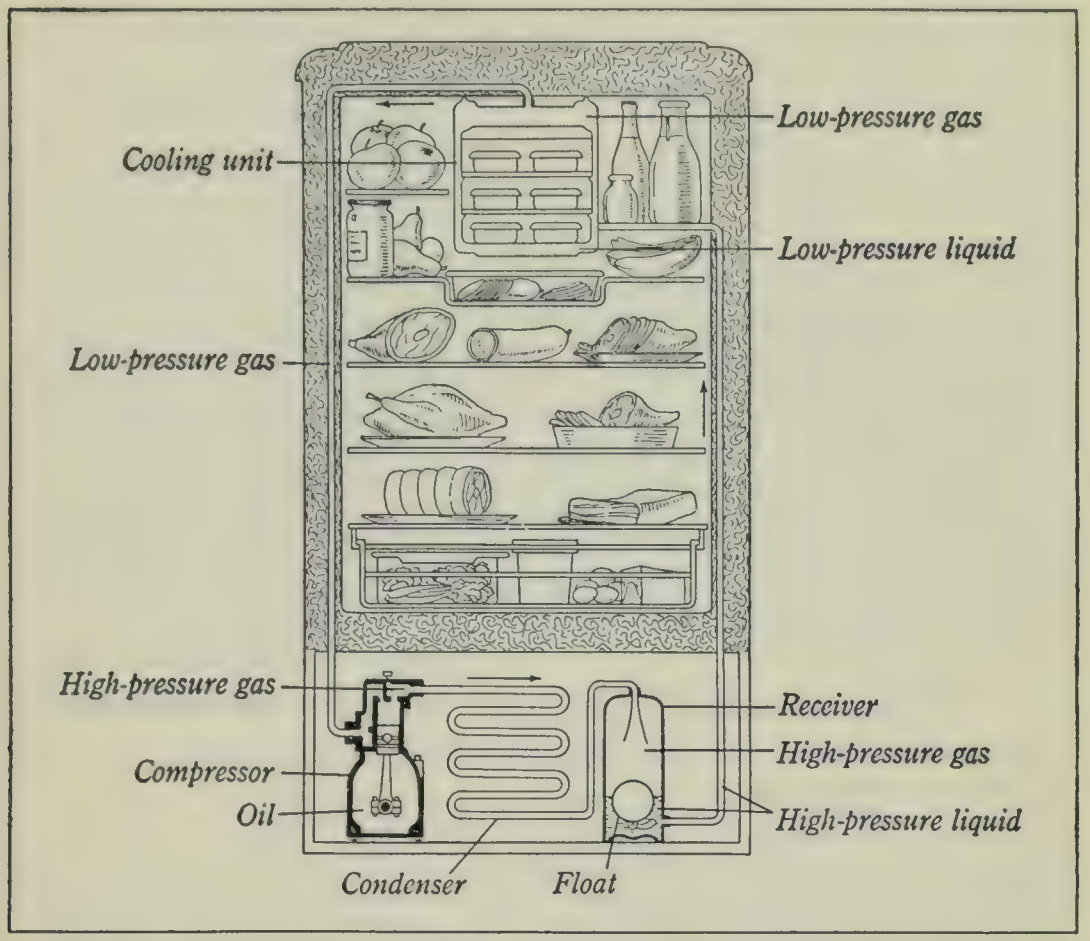


FIG. 139. One type of mechanical refrigerator. Can you explain its operation?

heat. Therefore the cold salt solution cannot easily get heat from outside, and most of the heat energy it absorbs is conducted from the cream, cooling the cream till it freezes.

The fact that a solution of some substance in water freezes at a much lower temperature than does pure water is used not only in freezing ice cream but also in protecting automobile radiators from freezing. Alcohol, glycerin, or other suitable substance is put into the radiator. It dissolves in the water. The solution would freeze only at a temperature below the freezing temperature of water.

The vacuum bottle. The vacuum bottle is a double-walled bottle with a vacuum between the walls (Fig. 140). The vacuum bottle keeps hot liquids hot by preventing their heat energy from

escaping rapidly. It keeps cold liquids cold by preventing heat energy from entering rapidly. Since there is almost no air between the walls, there is almost no convection of heat energy inward or outward. Heat energy enters or escapes slowly through the cork and the top by conduction. When the contents of the bottle are hot, there is a little heat loss by convection between the contents and the cork. The inner surface of the outside wall and the outer surface of the inside wall are silvered like a mirror. They are therefore good reflectors and poor absorbers of radiant heat energy. Consequently radiation of heat energy inward or outward is greatly reduced.

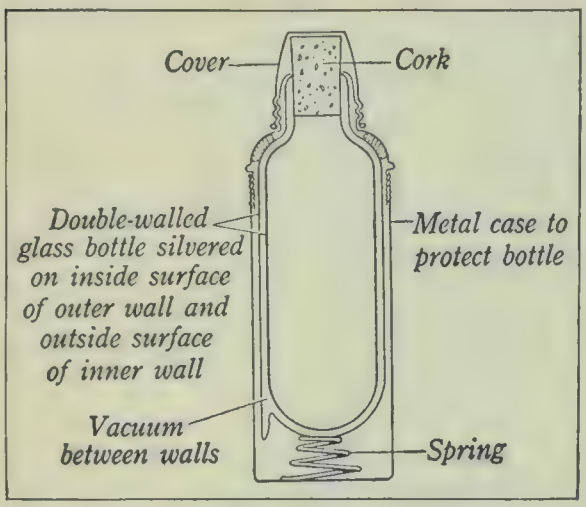

Cover
Cork
Double-walled glass bottle silvered on inside surface of outer wall and outside surface of inner wall
Metal case to protect bottle
Vacuum between walls
Spring

FIG. 140. The vacuum bottle. What heat insulators are used in the vacuum bottle?

Vacuum bottles of bright metal are now made. These are less easily broken than are glass-walled bottles, but they have the disadvantage arising from the fact that the metal is a better conductor than the glass. Huge milk tanks of metal, made like vacuum bottles and mounted on trucks and flatcars, are now being used to convey milk over long distances.

The cooling system of an automobile. Radiation, convection, and conduction are all used in keeping the automobile engine sufficiently cool. The heat from combustion in the engine is conducted through the walls of the cylinder to the water in the water jacket (Fig. 141). As the water heats, convection currents are set up in the direction indicated by the arrows. A water pump keeps the water moving strongly in the same direction. As this hot water circulates through the radiator its heat is conducted through the radiator walls. It is absorbed by the colder air which is forced through the radiator by the motion of the car and the whirling of the fan. Some of the heat is radiated away from the walls of the water jacket and the radiator and from other heated parts.

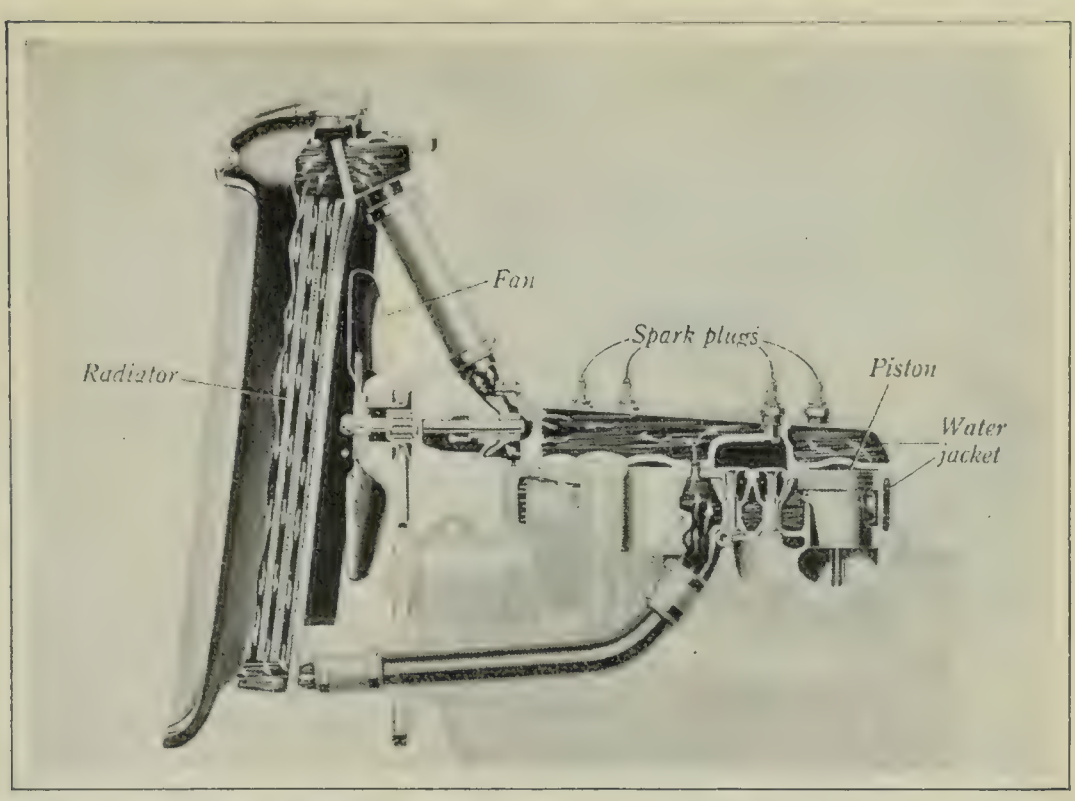


FIG. 141. Convection currents in the cooling system of an automobile. Can you explain what causes the convection currents to start?

Self-test on Problem XII–C. (*Do not write in the book.*) **1.** Water is frozen by (1) adding cold to it; (2) putting salt into it; (3) adding ammonia to it; (4) taking heat from it; (5) suddenly raising its temperature.

2. Water in which some substance has been dissolved freezes at a *higher* temperature than pure water.

3. A solution of alcohol in water *seldom freezes* at 0° C.

4. Heat passes between the walls of a vacuum bottle by *conduction.*

5. The surfaces of the walls of the radiator and other heated parts of an automobile are unpolished rather than polished in order to make the *conduction* of the heat away from the engine faster.

Problem XII–D · How is our Knowledge of Heat Energy Applied in Clothing?

***Clothing materials.** The first clothing consisted of the skins of animals. After thousands of years man learned to weave cloth out of animal hair, such as wool (Fig. 142) and camel's hair; out of plant fibers, such as cotton and flax; out of threads produced by silkworms; and recently out of wood (rayon).

How do clothes keep us warm? We often hear the expression "warm clothing." Clothing, however, is neither warm nor cold. It cannot give heat energy to the body. It can merely help the body to conserve[1] the heat which the body secures mostly from the oxidation of food. In winter, when the air is much colder than the body, we must prevent the body from losing its heat too rapidly to the air. We must diminish the radiation, convection, and conduction of heat away from the body. Then, too, the body gives off about half a gallon of water a day in the form of perspiration. We must prevent too rapid evaporation of this perspiration from the skin in winter, since much heat is always used in evaporating a liquid. You can prove the truth of this statement by pouring a few drops of alcohol on your hand and noting the sense of coolness produced as the alcohol evaporates.

Painting by E. I. Couse

FIG. 142. A Navajo woman weaving a woolen blanket in Arizona. Special Report: How many kinds of cloth are made of wool? cotton? silk? flax?

Clothing breaks up air spaces around the body and hence diminishes convection from the body. It also stops considerable radiation from the body. If we wore no clothes we should lose little heat by conduction, because air is a very poor conductor of heat. Some kinds of clothing materials conduct heat readily. Therefore in winter our problem is to use clothing that does not do this.

Winter clothing. It is easier to prevent conduction of heat away from the body in winter by wearing several thin garments than by wearing the same weight of clothing in one garment, because of the thin layers of air between the garments. The more air spaces cloth contains in its weave the less readily it conducts

[1] *Conserve* (kon serv'): to consume in sensible ways and without waste. *Conservation* (kon ser va'shun): the act of conserving.

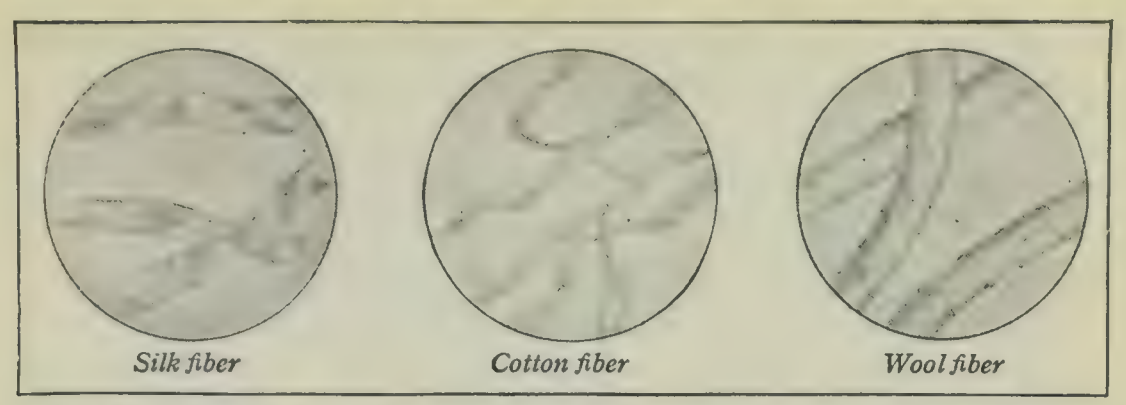


FIG. 143. Clothing fibers as seen under a microscope. **Question for Debate:** *Resolved*, That animal products have proved a more important source of clothing materials than have vegetable products[1]

heat. Hence wool is better than either cotton or silk for winter wear, because (1) it can be woven more loosely; (2) it can be woven with a nap which makes still more air spaces; and (3) it absorbs moisture, such as perspiration, very much more slowly and also evaporates it very much more slowly than do other kinds of cloth.

All-wool material is not satisfactory for inner garments, because (1) it is not comfortable to the skin and (2) it is likely to shrink when washed, thereby closing the air spaces. The best garments to wear next to the skin in winter are a mixture of silk and wool, and the second best are a mixture of cotton and wool.

Animal fur is excellent for cold climates because it contains more air spaces than the most loosely woven cloth. It is estimated that the fur of some animals contains more than 95 per cent of air and less than 5 per cent of hair.

Summer clothing. In summer our problem is not to conserve the body heat but to get rid of it. The qualities which make cotton, silk, and linen less desirable for winter wear make them more desirable for summer wear. These substances are also better than wool because they remove perspiration more readily. Linen outer garments especially are excellent for summer wear, because linen absorbs and evaporates moisture more rapidly than does any other kind of cloth.

White and green are better summer colors than black, red, or orange, because they reflect more of the sun's radiant heat and

[1] From McPherson, Henderson, and Fowler's *Chemistry for Today*.

absorb less of it. It is important, however, that summer clothing allow certain of the sun's rays, which are especially necessary to health, to penetrate readily to the body. It is claimed that rayon allows more rays to pass through than do other materials, though cotton and silk also permit many of these rays to pass through.

Experiment 40. How do various cloth fibers differ from each other? With a strong hand lens or a microscope examine the fibers of wool, silk, linen, cotton, and flax. Examine also the hairs from furs of various sorts. Make drawings similar to Fig. 143 showing the differences which you observe.

Self-test on Problem XII–D. (*Do not write in the book.*) 1. Clothing is warm provided it *prevents* the loss of heat energy from the body.

2. The greater the amount of air trapped among the fibers of clothing, the *cooler* the clothing will be.

3. The more rapid the evaporation of perspiration from the body, the *cooler* we shall be in *winter* and the *warmer* in *summer.*

4. Animals would be *warmer* in winter if their fur lay flatter and closer to their skins.

5. Clothing which keeps out the sun's *rays* is *more* healthful than that which admits them.

Problem XII–E · How is Heat Energy used in our Homes?

***Early attempts to heat the home.** Primitive man lived in caves when he could find those suitable for habitation. These caves were never very cold. They had the further advantage of remaining at nearly the same temperature all the year. When, after thousands of years, man learned to use fire, he began to heat his caves and rude huts with open fires. The smoke which was carried along with the convection currents was doubtless very annoying. He had to accept the smoke, however, in order to get the heat.

*After many centuries of development man learned, either by chance or by experiment, that if he left a hole in the roof of his rude dwelling most of the smoke would escape through the hole (Fig. 144). Of course there was still too much smoke for comfort. The Romans tried to avoid the disadvantages of open fires in their houses. They built a compartment beneath the floor through which passed hot gases from the fire. These gases heated the floors of the rooms above by conduction.

Ewing Galloway

FIG. 144. Blackfoot Indian camp, Montana. How did the Indians solve the fire-and-smoke problem?

*The fireplace, built into the wall with a chimney outside, marked a great forward step in the heating of houses. It furnished the idea which after many centuries led to the invention of our modern stove and hot-air furnace.

***Modern devices for heating the home: 1. The fireplace.** The fireplace in some form has been in use for centuries. Its increasing use entitles it to be classed among the modern devices for heating the home as well as among those of ancient times (Fig. 145, *A*). It has the advantages (1) of being cheerful, (2) of not taking up space in the room, and (3) of insuring good ventilation, because fresh air enters round the doors and windows while the stale air goes out through the chimney. It also has a number of important disadvantages. Much fuel is wasted, since most of the heat from the combustion is carried by convection directly up the chimney. Moreover, it heats the room almost entirely by radiation and therefore unevenly. There are two reasons for this: (1) the radiant heat passes through the air without heating it to any great extent, and (2) the convection currents in the room are moving toward the fire.

***2. The stove.** Stoves have been in use less than two centuries. Until very recently the heating stove consisted of a closed iron

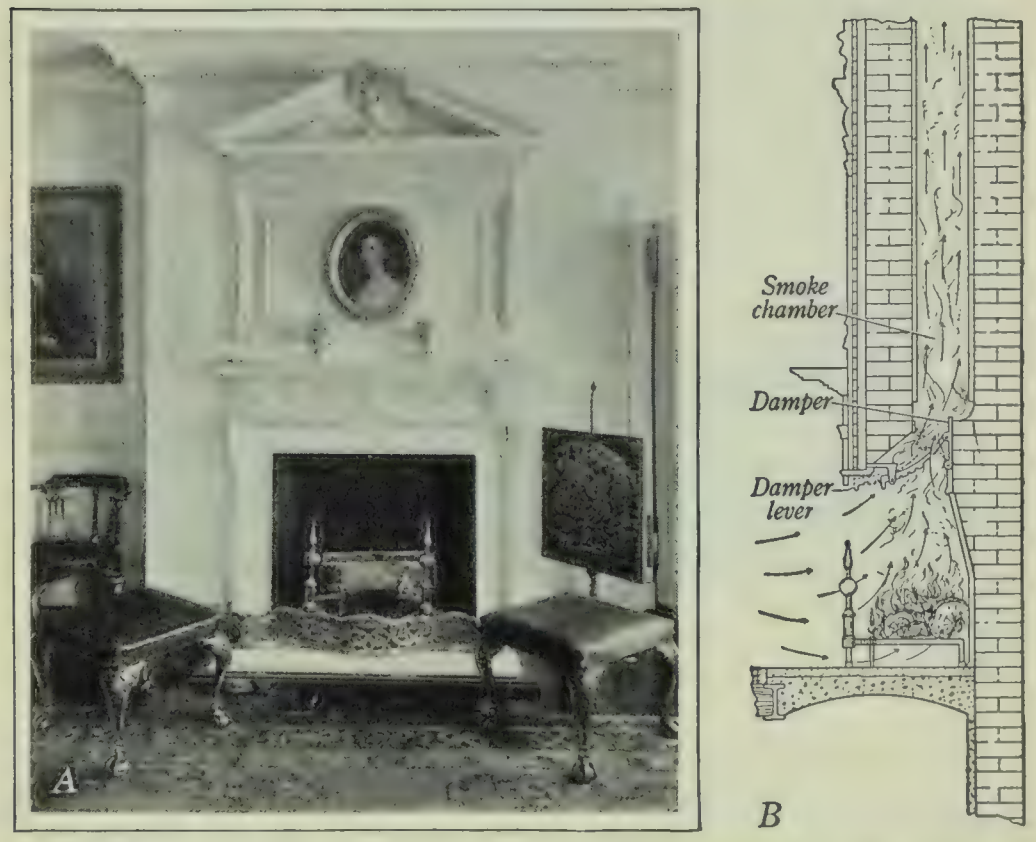


FIG. 145. *A*, the fireplace in the old Van Cortlandt Mansion in New York City; in this room, famous in colonial history, Washington and other leaders were entertained. *B*, diagram of a modern fireplace. The dotted lines indicate the position of the closed damper. Why do the convection currents move in the direction of the arrows?

box with a smoke pipe. Within recent years very great improvements have been made in the heating stove, making it one of the most effective of all means of heating a room.

*The modern heating stove is like an old-fashioned stove inside a steel jacket. It heats the room chiefly by convection, though it also heats by radiation. The heat energy from the burning fuel is conducted through the steel body of the stove. This heats the air between the stove body and the outside jacket, causing convection currents.

*The modern stove (Fig. 146) is equipped with three drafts and a chimney damper. These together make it possible to control

the rate of combustion. When the fire is first started, the damper and the lower draft are opened and the other two drafts are

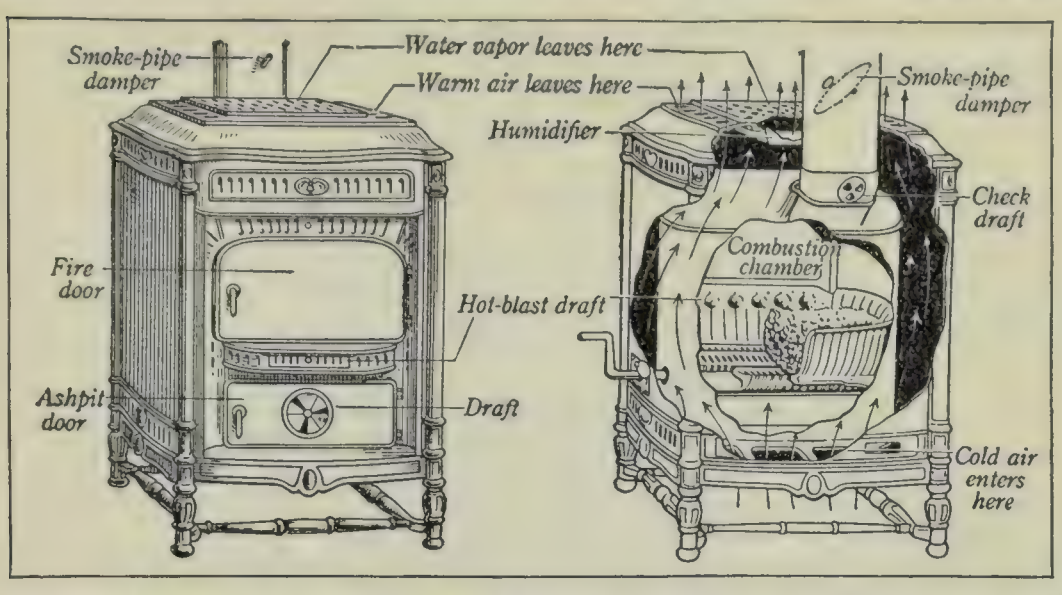


FIG. 146. A modern heating stove is a hot-air furnace. By referring to the text and these diagrams, explain how this stove operates

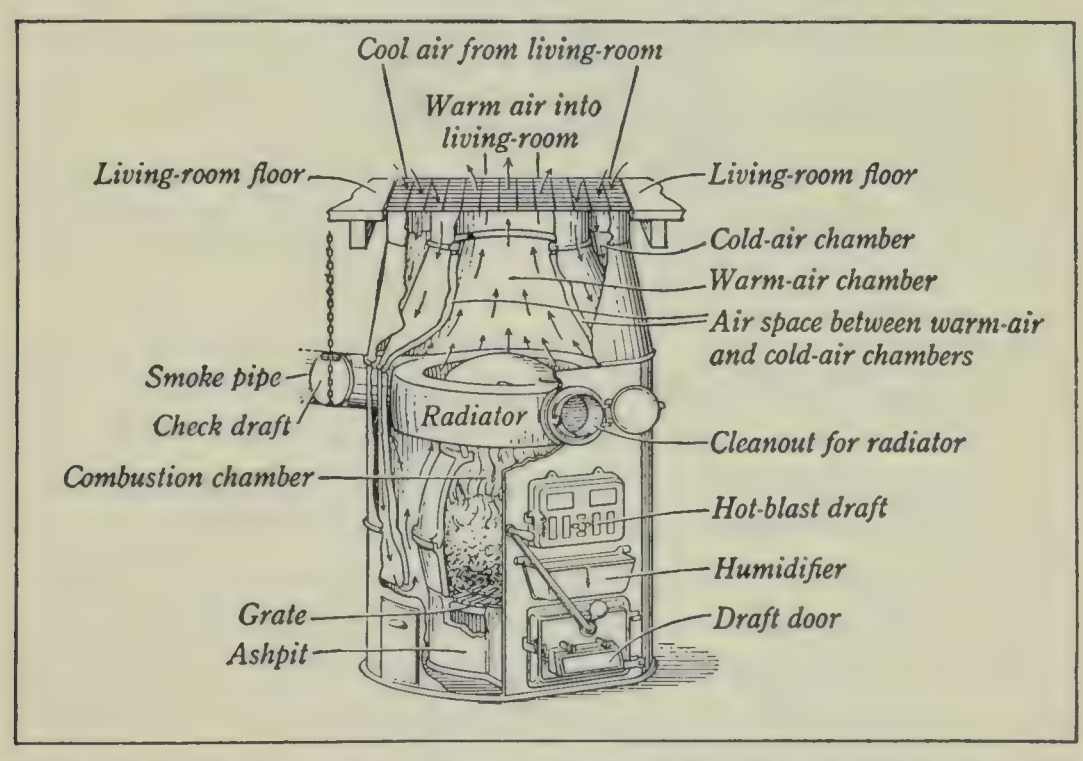


FIG. 147. A pipeless furnace. Can you explain why the air moves as indicated?

closed. This arrangement of damper and drafts allows the greatest possible amount of oxygen to pass up through the fuel. When the fire is burning vigorously the damper and the draft in the ashpit

door are closed to diminish the current of air through the fuel. The hot-blast draft is then opened. This allows oxygen to enter

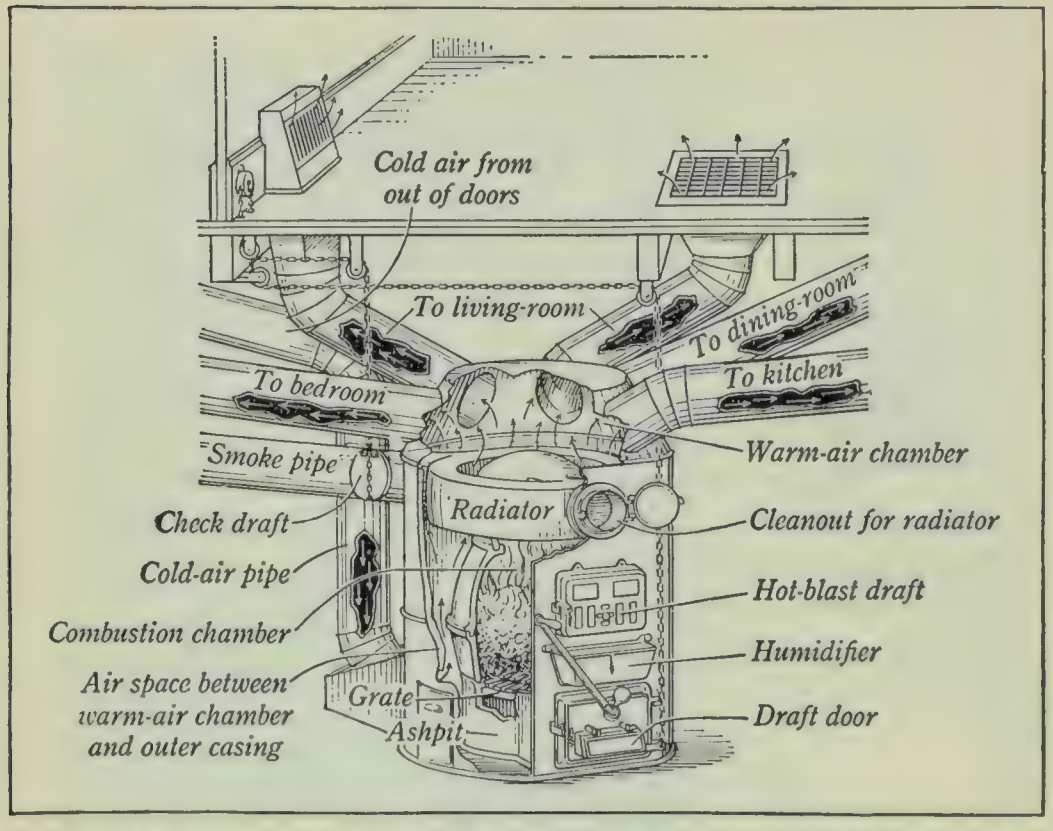


FIG. 148. A hot-air heating system. How are radiation, convection, and conduction used in this furnace?

the fire pot just above the burning coal or wood. Here it increases the oxidation of the combustible gases and also burns up many of the carbon particles which would otherwise make smoke and soot. By increasing the combustion the hot-blast draft increases the number of calories (see Glossary) from the fuel without increasing the amount of fuel which is being burned. If it is desired to make the rate of combustion still slower, the check draft is opened. Cold air is forced into the smoke pipe through this damper, thereby reducing the amount of air which enters the smoke pipe from the fire pot.

*3. **Hot-air heating.** The pipeless hot-air furnace (Fig. 147) uses the same principle as the hot-air heating stove which has just been described. The air that enters the heating chamber of the furnace is air from the house. Consequently it is already partly warmed.

*The ordinary hot-air furnace is equipped with pipes which carry the hot air to the various rooms (Fig. 148). Hot-air heating is commonly used in homes and frequently used in schools and other public buildings. Sometimes fans are used to assist in pushing the convection currents through the pipes.

*4. Hot-water heating. In the hot-water heating system, the furnace is equipped with a water jacket. This surrounds the combustion chamber. The heat energy from the burning fuel passes by conduction through the wall of the furnace to the water, which it heats to about 180° F. Convection currents are set in motion in the water jacket and pipes (Fig. 149). The heat energy given off by the water in cooling is conducted through the metal of the radiators. Part of this heat is radiated through the room, but most of it sets in motion convection currents which heat the room evenly.

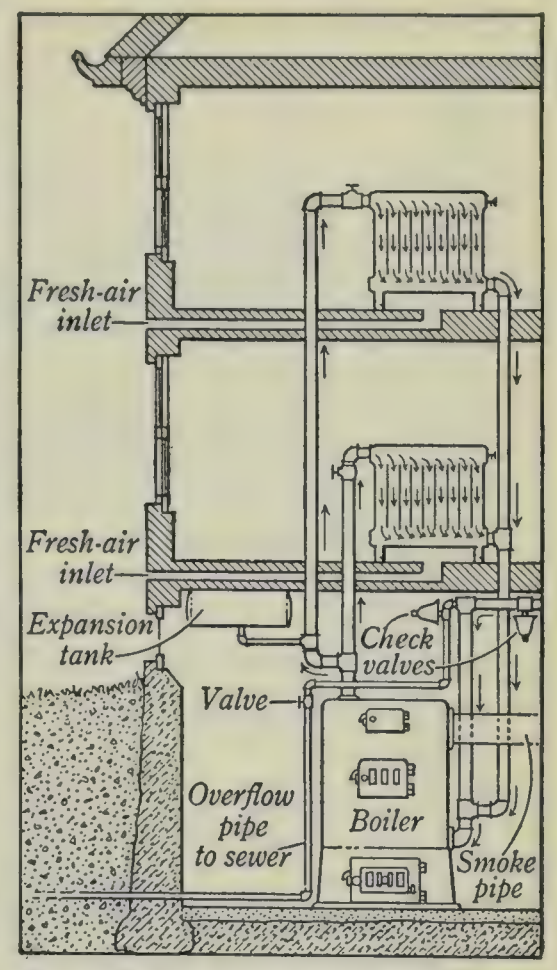


FIG. 149. Diagram of a hot-water heating system. Does the hot-water system heat the house chiefly by radiation, convection, or conduction?

*5. Steam heating. In the steam heating system (Fig. 150) the boiler is partly filled with water. This is raised to the boiling point and evaporated by the heat from the burning fuel. The steam produces sufficient pressure in the tank to force some of the steam up through the riser pipe into the radiators. Some of the steam is cooled so much in the riser pipe that it condenses, but most of it condenses in the radiators. When the steam condenses, it gives up heat energy. This is conducted through the radiators and distributed through the rooms by radiation and convection. Steam heat is commonly used for large buildings and for groups of buildings heated by a central heating plant.

*Summary: three methods of home heating compared. Of the three heating systems the hot-air system is the cheapest to install.

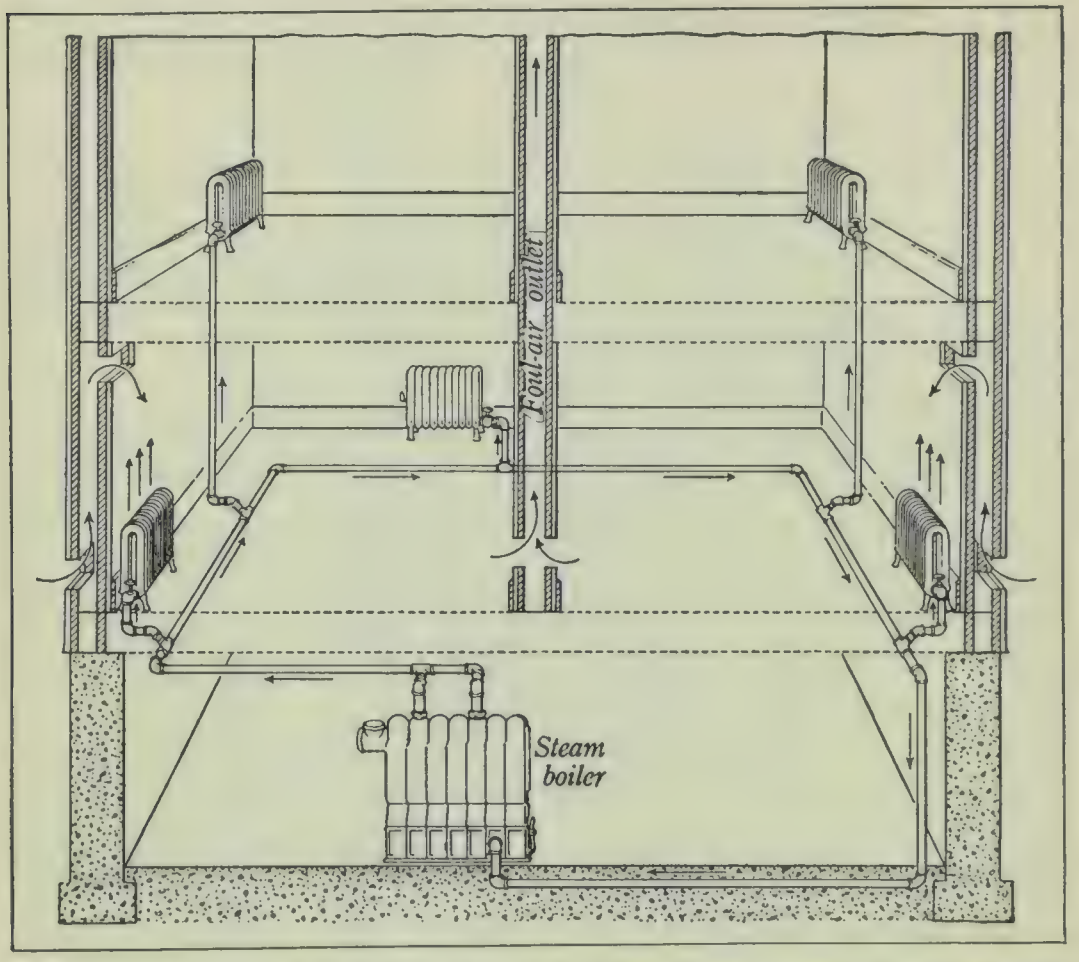


Fig. 150. Diagram of a steam heating and ventilating system. How does the steam heating system use radiation, convection, and conduction?

It begins to supply heat to the rooms soonest after the fire is started. It gives least heat energy to the rooms for the amount of fuel burned. Moreover, it is liable to allow some of the products of combustion to leak into the hot-air chamber and thence into the rooms with the hot air. Also it scatters more dust about the house than either a hot-water system or a steam heating system. The hot-water system is slow to heat and is the most expensive to install, but once the water becomes hot it maintains a steady, even temperature. With the hot-air and steam systems, on the other hand, the temperature of the rooms is likely to vary greatly. The steam heating system is less expensive to in-

stall than the hot-water system, and probably gives more heat for the amount of fuel burned. The hot-air system circulates

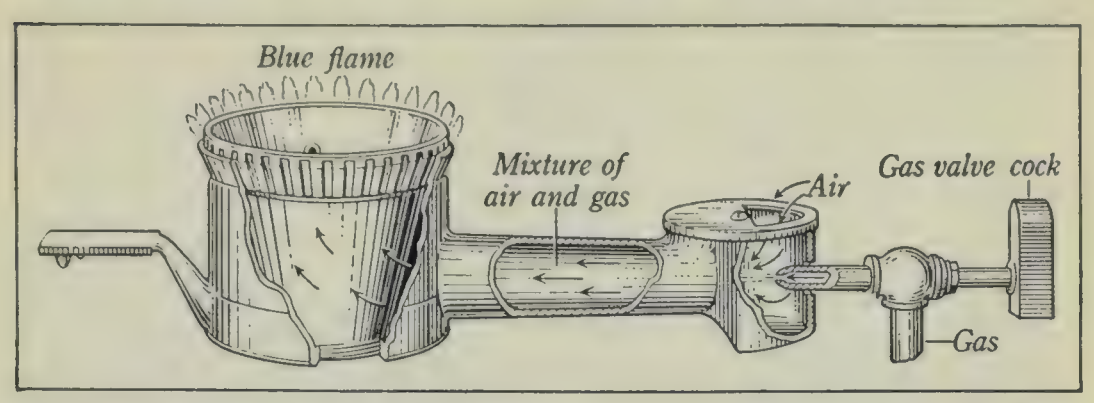


FIG. 151. Diagram of a gas-range burner. Can you explain its operation? What are some of the products of combustion?

plenty of fresh air throughout the rooms, but the other two systems do not. With steam or hot-water heating, therefore, either the windows must be opened or special entrances for fresh air must be placed under the radiators. It is easier to maintain the proper amount of moisture in the air with a hot-air system.

Modern cooking ranges. Before stoves were invented all cooking was done over open fires or in fireplaces. The invention of the cookstove made possible both greater convenience and greater economy of fuel.

Where gas can be obtained, the gas range is rapidly taking the place of coal and wood ranges. It is cleaner and more convenient and cooks the food more quickly. Gas burners have the disadvantage, however, that the products of combustion escape into the room. Where natural gas is obtainable, it is cheaper than wood or coal for cooking. Fig. 151 shows the construction of the burner of a gas range.

Where electricity is not too expensive, the electric range is becoming more and more common. It is probably the cleanest and the most convenient of all the ranges. Electric heaters also are convenient and clean.

Self-test on Scientific Principles. How many examples of this scientific principle can you find in Problem XII-E? Can you think of other examples?

"Differences in temperature at different places result in air currents."

Self-test on Organization of Facts. Write on a sheet of paper the headings "Hot-Air Heating," "Hot-Water Heating," and "Steam Heating." Under each give in parallel columns its advantages and disadvantages, thus:

HOT-AIR HEATING

Advantages	Disadvantages
1. _ _ (?) _ _	1. _ _ (?) _ _
2. _ _ (?) _ _	2. _ _ (?) _ _
3. _ _ (?) _ _	3. _ _ (?) _ _
Etc.	Etc.

Self-test on Problem XII–E. (*Do not write in the book.*) **1.** The fireplace heats the room chiefly by *convection.*

2. A heating stove heats the room chiefly by *conduction* and *radiation.*

3. Smoke escapes from stoves and furnaces by *conduction.*

Problem XII–F · How are Buildings Constructed so as to Conserve Heat Energy?

How pioneers solved the heating problem. When the pioneers first settled in the prairie regions, many of them found on their

FIG. 152. A primitive and a modern house with dirt walls. *A* was made by Indians in New Mexico; *B* is a modern city house in Michigan. What advantages are derived from having the wall so thick?

land no materials suitable for building houses. It was impossible for them to have building materials shipped to them, because there was no way of securing anything from a distance except by wagon. They solved their problem by making sod or dirt houses

Kaufmann-Fabry

FIG. 153. Glass-walled building at the Century of Progress Exposition, Chicago, 1933–1934. What advantages and what disadvantages of glass as a building material can you suggest?

(Fig. 152). These were partly underground. They dug a shallow basement to serve as the floor and part of the walls. They then built the remaining walls of dirt, which was sometimes mixed with straw, and roofed the cabin with sod. These houses were sufficiently warm during the fiercest winter storms.

Conserving heat in the house. Effective heating consists not only in producing heat but also in conserving it in the house. We frequently hear it said that a house is "warmly built," or that it is a "warm" house. This statement usually means that the builder has made practical application of his knowledge of convection and conduction in constructing the house. This he does in two ways: (1) by making the house tight to keep out cold winds, and (2) by using materials in the ceilings, roofs, and walls which prevent the rapid escape of heat energy from the house. A house which is warm in winter is cool in summer, because the same construction which prevents the escape of heat energy in winter also prevents its entrance in summer.

Weather stripping, usually of felt or of sheet copper or zinc, is finding increasing use to prevent drafts around windows and out-

side doors. Most of the heat energy which is lost from a building, however, escapes by conduction through the walls, roof, and windows, and thence by convection and radiation from the outside surfaces. Any building material which is a good heat insulator prevents heat from escaping by conduction (Fig. 153). Air spaces are introduced into buildings because air is a good heat insulator. Thus stone walls, which are good conductors and are therefore poor insulators of heat energy, are made into good insulating walls by building the walls double so as to leave air spaces between them. The same is done with brick walls.

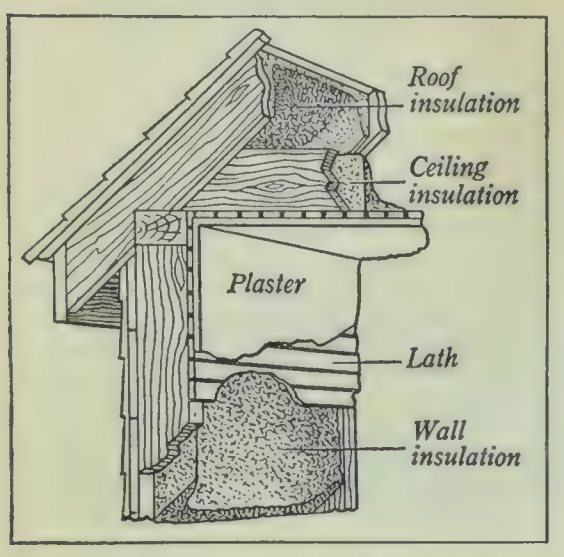


FIG. 154. Diagram of a modern heat-insulating construction of house wall, ceiling, and roof. In how many places in this diagram is air used as a heat insulator?

Building tiles and concrete brick are made with air spaces inside. Storm doors and storm windows, which consist of an extra door or window shutting in an air space, are commonly used where winters are severe. Wood is a fairly good insulator, but a double-walled wooden house is cooler in summer and warmer in winter than a single-walled house because of the air spaces between the walls. Such air spaces must be broken up with partitions or with incombustible loose filling to reduce convection within the walls, especially in case of fire.

Artificial insulating materials. Artificial heat-insulating materials of several kinds are now being manufactured. These are made of materials which themselves are poor heat conductors and are constructed in such a way as to provide abundant air spaces. Coverings composed of asbestos or magnesia are used on furnaces, steam pipes, hot-air pipes, and hot-water pipes to reduce heat losses. Insulating materials composed of hair, cork, various kinds of plant fibers which have first been made incombustible, and some mineral substances, especially gypsum, are used as wall

fillings and in plaster, in plasterboards, and in wallboards. It is claimed that an inch thickness of one of these materials in the roof and another half-inch thickness in the walls (Fig. 154) will reduce the fuel bill one third.

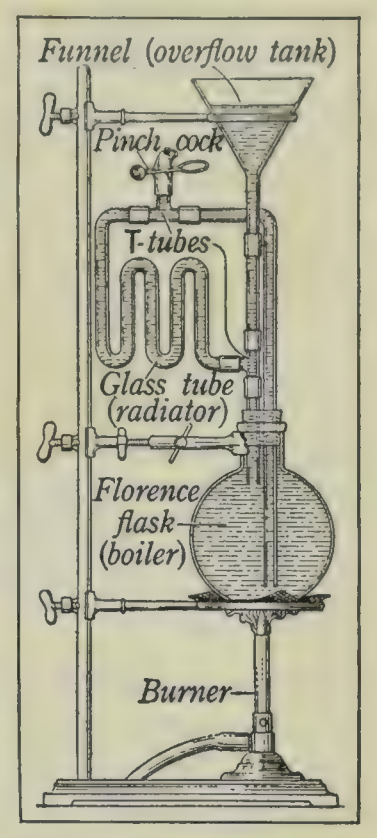


FIG. 155. Classroom model of a hot-water heating system. In this model indicate what corresponds to each part of Fig. 149, p. 215

Self-test on Problem XII–F. (*Do not write in the book.*) **1.** The dirt, the straw, and the sod used in building the sod houses were good *conductors* of heat.

2. Houses are warm in winter if the passing of heat energy *into* the house is prevented; and they are cool in summer if the passing of heat energy *out of* the house is prevented.

3. In warmly built houses *more* use is made of solid than of porous materials.

4. Houses with metal walls and roofs would be *warmer* in winter than houses with wooden walls and roofs.

5. In building warm houses *little* use is made of air spaces in the walls and roofs.

6. A *greater* quantity of heat is obtained for the same amount of wood burned in a stove *than* in a fireplace.

7. *More* useful heat would be obtained from a cord of wood burned in an Indian wigwam than in a modern home.

Self-test on Scientific Principles. 1. How many examples of the following principle can you find in this chapter: "Whenever two bodies of different temperatures touch each other, the warmer always gives up heat energy to the colder"?

2. It is often correctly said that a vacuum bottle conserves the heat of a hot liquid in it. Is this statement the same as saying that the vacuum bottle furnishes a good example of the principle of conservation of energy? Explain.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why are single-walled houses more difficult to maintain at an even temperature than double-walled houses?

2. Why is a house with an attic cooler in summer and warmer in winter than one without an attic?

3. Why is a lath-and-plaster house a "warm" house?

4. A certain woman wanted to save money by making her ice last longer. She therefore wrapped it in several thicknesses of newspaper and an old quilt before she put it into the refrigerator. The ice did melt very slowly (Why?), but she learned after a few days that hers was a very poor way to save money. Explain.

5. What part of the artificial ice machine (Fig. 138, p. 204) is like the water jacket of the automobile shown in Fig. 141, p. 207?

6. Why are brick, stone, sod, and dirt-walled houses cool in summer and warm in winter?

7. The Multnomah Indians of Oregon hit upon the idea of building a fire in the middle of a large circular pit made in the dirt floor of the permanent council house. When they sat round the edge of the pit with their feet hanging down inside, they were little annoyed by the smoke, which escaped through a hole in the roof. Explain.

8. Why is there usually a strong wind toward a burning building or a forest fire?

Project. To make a simple model of a hot-water heating system set up apparatus as in Fig. 155. Fill the apparatus from the overflow tank (funnel), but open the pinchcock above the radiator while filling the apparatus. Why? Do not allow the water to boil.

Special Reports. 1. What tests may one use to determine the various kinds of fibers in cloth? How do cloths made from different fibers differ from each other? For what purposes is each material best suited? What mixtures of fibers are common in clothing? How are artificial silk, muslin, mercerized cotton, and other special kinds of cloth made? What is shoddy?

2. Describe gas furnaces, gas fireplaces, kerosene ranges, and gasoline ranges, their construction and methods of operation.

Books for Reference

KINNE and COOLEY. Shelter and Clothing. The Macmillan Company, New York.

CARPENTER, F. G. How the World is Housed. American Book Company, New York.

UNIT V · *How Weather and Climate Affect Us*

PROBLEMS DISCUSSED IN THIS UNIT

There is probably no topic which is discussed more frequently than the weather. One can readily understand the general interest in the weather because it is of so much importance to everybody. On the basis of the weather or the forecast of the weather that is expected we decide whether we shall have the picnic we have planned; whether we shall go bathing in the lake; whether we shall start on a vacation trip; whether we shall put alcohol in the automobile radiator; and countless other questions. The weather is the cause of many puzzling problems which the business man must solve: should he buy a large or a small stock of warm-weather garments; will the demand for ice or for coal be great or small; and the like.

The weather even affects the fates of nations. It is stated that Napoleon might have conquered Russia, and later the rest of the world, had it not happened that in the winter in which he invaded Russia severely cold weather began weeks earlier than usual.

The climate is no less important than the weather. It determines whether our houses shall be warmly built, with effective heating systems; whether it is prudent to carry storm insurance on our homes; whether it will be possible to grow certain crops; whether a certain business can be carried on profitably or not at all; and the like. This unit will be devoted to a discussion of these problems:

What are the causes and the nature of winds and storms?
Of what interest and importance is humidity?
What is the relation of humidity to clouds and precipitation?
What is the nature of the work of the United States Weather Bureau?
What are the factors that influence climate?
How is climate related to living things?

Chapter XIII · Useful Knowledge about the Weather

Questions this Chapter Answers

What is weather?
Why does the earth's surface heat unequally?
What are the characteristics and the importance of various winds and storms?
What are the nature of relative humidity and its relation to health?
What are the characteristics of various cloud forms?
How are the various forms of precipitation caused?
What are the nature and the importance of the water cycle?
What are the nature and the importance of the work of the Weather Bureau?

Problem XIII–A · What are the Causes and the Nature of Winds and Storms?

Weather factors. If you were to consult the weather report and weather forecast in the daily newspapers or were to listen to the "Weather Man" on the radio, you would note such terms as "barometric pressures," "storm area," "precipitation," "rising temperatures," "increased cloudiness," and "moderate winds." These are related to the weather factors pressure, temperature, and humidity. In earlier chapters we learned how the barometer is made and how it measures air pressures, how the thermometer is used in measuring temperatures, how the convection currents are caused, and how water is evaporated and condensed. We shall now consider these topics and others as they relate to the weather.

Unequal heating of the earth's surface. As we have already learned, the air is heated very little by the sun's rays. It is heated, however, by conduction through contact[1] with the earth's surface. It is also heated by convection currents rising from heated areas. There are a number of causes for the unequal heat-

[1] *Contact* (kon'takt): the touching of two objects.

Metropolitan Museum of Art

FIG. 156. Only horizontal air currents such as might move a sailboat are considered as winds. Can you think of any uses that are made of the energy of vertical currents?

ing of different areas of the earth's surface: (1) Some materials absorb more heat than others, both because of their nature and because of their surfaces. Thus, on a bright day the shore of a lake will be warmer than the water of the lake, (*a*) because the darker-colored ground absorbs heat energy more readily than the water; (*b*) because the heat energy goes more deeply into the water before it is absorbed, and consequently has more matter to heat; (*c*) because it takes several times as much heat energy to raise the temperature of water a degree as it does to make a rise of one degree in the temperature of an equal amount of ground; and (*d*) because the smooth, mirror-like surface of the water reflects away more of the radiant heat energy than does the rough surface of the shore. (2) The angle at which the sun's rays strike the surfaces of objects affects the amount of heat energy which is absorbed. Thus a level region or plain will absorb much more radiant heat than will a near-by cliff. (3) The height of a place above sea level likewise affects its temperature. Thus, even in winter, it will often be uncomfortably warm in the sunshine on a

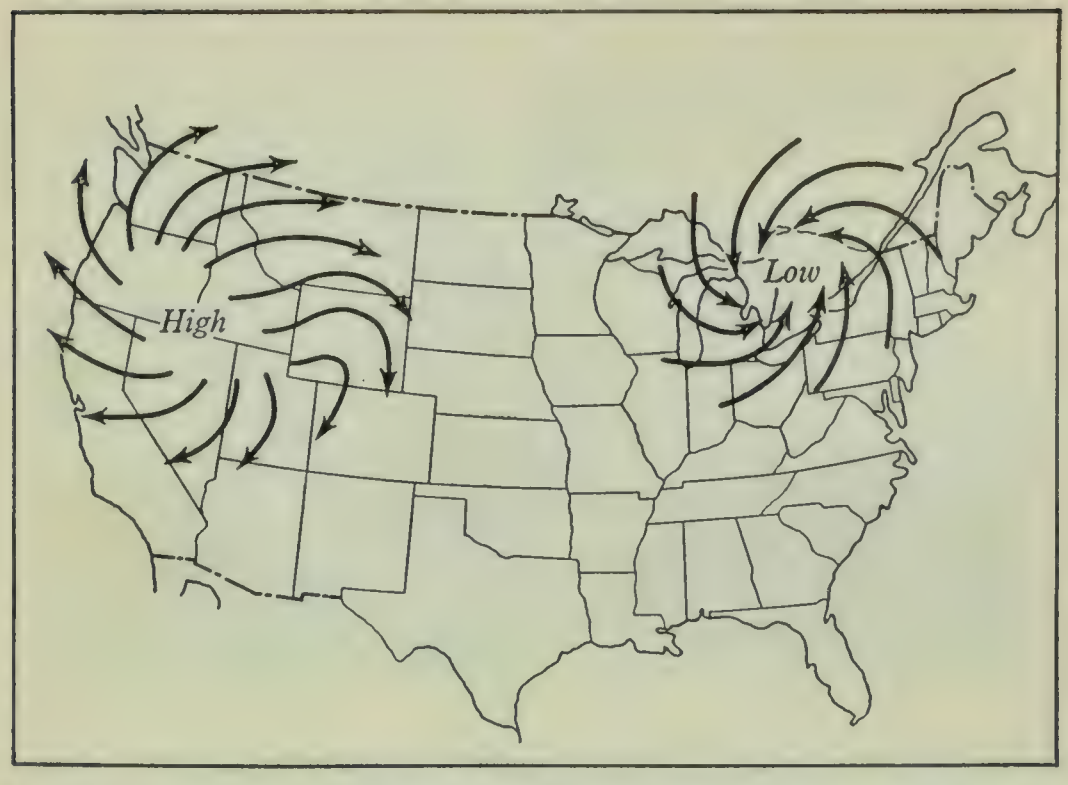


FIG. 157. Diagram of a high and a low. Consulting this diagram and the text, compare a cyclone and an anticyclone. (See "To the Student," p. xvi)

mountaintop though the temperature in the surrounding valleys may be below freezing. The reason is that at the levels of the mountaintops there is less air to absorb the sun's radiant heat. When the sun goes down, however, the mountaintop will very soon become much colder than the valleys. The reason is that the air is much denser in the valleys and therefore it serves as a blanket preventing the rapid escape of heat energy.

Characteristics of winds. As has been previously stated, differences in temperatures of various earth areas produce differences in air pressures. Convection currents, or winds, result from these differences in pressures (Fig. 156). The greater the differences in pressures the stronger are the winds. These winds may be local or they may be regional, that is, affecting a considerable area. Local winds may be brief and of little effect, like the small "whirlwinds" one may observe on almost any summer day, or they may be extremely violent, as, for example, a tornado. A regional wind often lasts for many hours and may be a gentle wind or a violent gale. There are also great air movements over vast por-

Keystone View

FIG. 158. A "thunderhead" over Omaha, Nebraska, just before the storm broke. Does this picture show any evidence of strong convection currents? Explain

tions of the earth. These have to do with climate rather than with weather. They will therefore be discussed in the next chapter.

*Cyclones and anticyclones. When on a ship at sea the barometer begins to "fall," the officers and crew at once make preparations for a storm. They know that a cyclone is approaching. A cyclone, or low (Fig. 157), is a great circular whirling area of air which has a barometric pressure lower than that of surrounding areas and usually less than 30.0 inches. A low may be as large as two thousand miles across, yet it rarely extends more than four or five miles above the earth's surface. Lows travel over the land as well as over the sea. In fact from one to three lows may be expected to pass across North America each week. They travel in general from west to east. The center may travel in a day over a distance of from a few hundred miles to more than a thousand miles.

The winds of a cyclone, or low, are not often violent, though occasionally they reach a speed of one hundred miles per hour. At that speed the enormous force against trees or walls of houses sometimes pushes them over. Weather conditions within a low

are often such as to cause storms, which may be accompanied by precipitation, that is, fall of rain, snow, sleet, or hail.

Cyclones are followed by anticyclones, or highs. These are also great whirlpools of air. In them the barometric pressures are higher than those of surrounding areas and are usually greater than 30.0 inches. Air currents flow inward toward the center of a low and outward from the center of a high. Air currents flow upward in the center of a low as in a great chimney. They flow downward in the center of a high. Lows and highs rotate, or whirl, in opposite directions (Fig. 157).

Thunderstorms. Thunderstorms occur in a low, usually in its southern part. They happen usually during warm summer weather, but sometimes during the winter and even at night. They are caused when warm currents heavy with moisture ascend rapidly (Fig. 158). As these currents strike the cold upper air their moisture is condensed. A heavy fall of rain or hail results. Lightning usually accompanies such a storm. The cause and nature of lightning will be discussed in Chapter XXI. A sharp breeze usually goes ahead of a thunderstorm.

***The tornado.** The tornado (Fig. 159) is the type of violent and destructive[1] storm sometimes incorrectly spoken of as a cyclone. A tornado occurs in a low, or cyclone, after a period of warm, calm weather. One explanation of the cause of tornadoes is this: The air next to the earth becomes heated, but convection currents are delayed. As a result there is next the earth's surface a stratum, or layer, of warm air. Above this, like an invisible roof, is a stratum of cold air. Finally the pressure of the expanding warm air becomes great enough to break through a thin portion of the colder stratum above. Immediately the warm air is pushed from every direction toward this hole, in much the same way that the water is pulled in every direction toward the drain when the stopper is removed in a washbowl. The result is a whirling wind of great violence covering a relatively small area. This tornado moves across the country in the general direction from southwest to northeast (Fig. 160) with the low, in somewhat the same way that an eddy[2] in a river travels with the current.

[1] *Destructive* (de struk'tiv): liable to destroy.

[2] *Eddy* (ed'dy): a small funnel-shaped whirl in water.

U. S. Weather Bureau

FIG. 159. A tornado. Note the dust cloud at the base. What do you think makes the tornado visible?

Fig. 160 is a map showing a section of the path of the tornado of March 18, 1925. This tornado swept across southern Illinois and Indiana in midafternoon, killing or injuring about four thousand people and causing millions of dollars' worth of property damage. The storm started in northwestern Arkansas, then swept northeasterly through the towns shown on the map and died out in central Indiana. The main path of this tornado was about one hundred sixty-five miles long and about three hundred feet wide. The force of the wind was so great that houses were moved from their foundations, sides of buildings were ripped off, timbers from wrecked buildings were carried as far as fifteen miles, and smaller objects were carried much farther. Damage of this sort is common in the path of a tornado.

Hot waves and cold waves. Sometimes, in summer, air from much warmer regions farther south is forced into a low. As this warm air flows northward over the country a heat wave results. Such a condition may last for several days. Soon, however, the low passes and its place is taken by a high, bringing cooler air from higher altitudes.

Just as we generally associate stormy weather with lows, so do we associate fair weather with highs. Yet some of our worst

FIG. 160. The path of a tornado. If you were facing a tornado coming directly toward you, what would it be safest to do: stand still? run toward the tornado? directly away from it? toward your right? toward your left?

winter storms occur during highs. Sometimes very cold air from high altitudes descending through the center of a high causes a cold wave. If the cold air strikes an extended area of warm moist air, a heavy fall of snow often results. Hard-frozen snow and sleet driven by winds is called a blizzard. In a blizzard it is often impossible for one to walk facing the wind. Men and animals blinded by the drifting snow sometimes become lost and freeze to death. Blizzards are most severe in the prairie countries, since in these open spaces the winds have a clear sweep over the land.

The incoming colder air of the blizzard is usually from the north or northwest, hence the name *norther* sometimes applied to these storms. The name *blizzard* is applied only in regions where snow falls; in the Southern states *norther* is more commonly used.

Hurricanes. Among the most terrible of all storms are the tropical cyclones, or lows, called hurricanes. These start in the

West Indies and usually sweep northwest along the Atlantic coast, sometimes visiting Florida. They are most common in late summer and early autumn. Because of the extreme violence of the winds which accompany the hurricanes they often do great damage to shipping and to the lowlands along the coast. In 1900 such a hurricane took an unusual path northwest from the West Indies across the Gulf of Mexico. The gale which accompanied it forced ahead of itself a huge wall of water. This wave reached Galveston, Texas, where it did great damage and caused considerable loss of life. Such storms on the North Pacific are called typhoons.

Self-test on Problem XIII–A. (*Do not write in the book.*) **1.** Outline the causes of unequal heating of different areas.

2. Winds blow from places where the pressure is *less* to places where it is *greater.*

3. Winds blow from places where the temperature is *high* to places where it is *lower.*

4. A cyclone, or *high,* is a great whirlpool of air in the center of which the pressure is *less* than 30.0 *inches.*

5. Precipitation occurs most frequently in a *high.*

6. A small, violently whirling wind is a (1) cyclone; (2) hurricane; (3) thunderstorm; (4) anticyclone; (5) tornado.

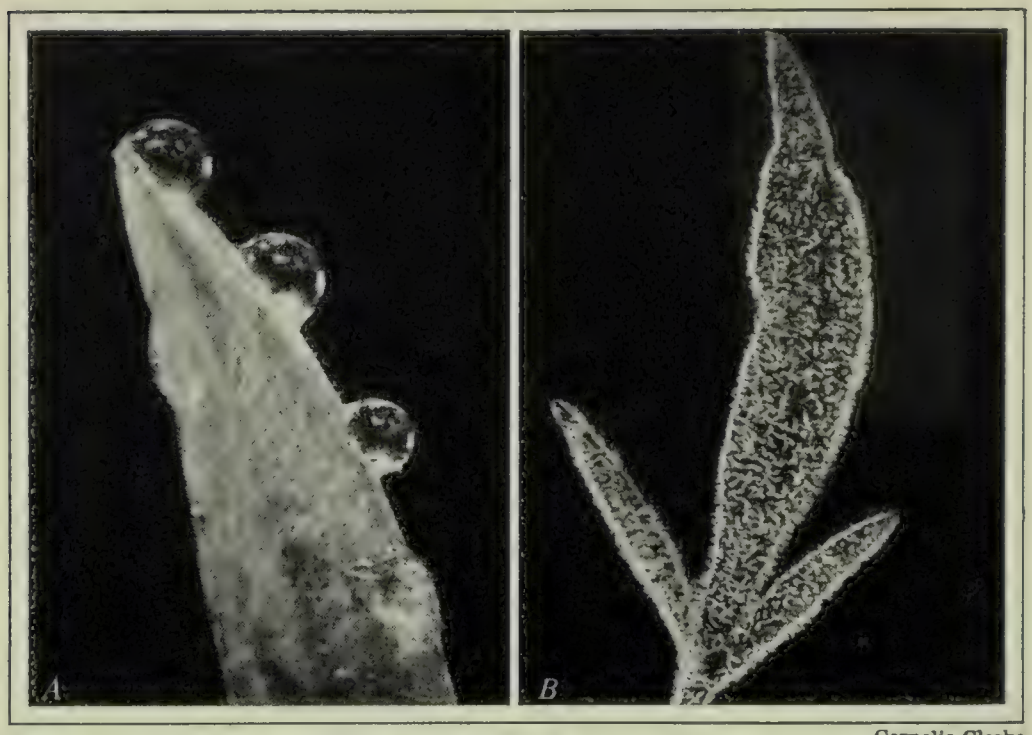
7. Highs and lows follow one another across the country in a general *north*-and-*south* direction.

8. Highs are *seldom* accompanied by fair weather.

9. Precipitation results when moist air is *warmed.*

Problem XIII–B · Of What Interest and Importance is Humidity?

Humidity and condensation. We have learned that all air is more or less humid; that is, that all air contains some water in the form of vapor. This water evaporates into the air from all bodies of water, from moist soil, from the leaves of trees,—from anything, indeed, which contains moisture. Whenever the air has all the water vapor it can hold, it is said to be saturated or to have reached the saturation point, or dew point. Saturated air is like a sponge which has taken up all the water it can possibly hold.



Cornelia Clarke

FIG. 161. *A*, dew on a leaf; *B*, frost on a leaf. **Exercise on Scientific Method (Making Inferences)**: How do you account for the fact that the water condensed as dew in one case and as frost in the other?

The warmer the air is, the more water vapor it will hold without becoming saturated. All air, however, will become saturated if it is cooled enough. If air is cooled to a temperature below its dew point, it will be unable to hold as vapor all the moisture it contains. Hence some of the water vapor will be condensed as dew, fog, rain, hail, sleet, frost, or snow (Fig. 161). The air will give up some of its water just as does a sponge when squeezed.

***Relative humidity.** During cold weather the air out of doors holds relatively little moisture. Yet it is not necessarily dry air, because it may be nearly saturated; that is, it may be holding about all the water vapor it is able to hold at its low temperature. But if this air is brought indoors and is heated, it at once becomes very dry air. The reason is that it is not so nearly saturated as it was when it was colder, because as it was warmed it became able to hold larger quantities of water vapor.

To illustrate, the air when cold may have been nine tenths, or 90 per cent, saturated. But the same amount of water vapor which nearly saturated it when it was cold was only enough to

make it two tenths, or 20 per cent, saturated when it was heated. The extent to which air is saturated, expressed in per cents, is called the relative humidity. If air at a given temperature holds only half the water vapor it might carry, it is relatively only half as humid as it might be; that is, its relative humidity is half, or 50 per cent, of what its humidity might be.

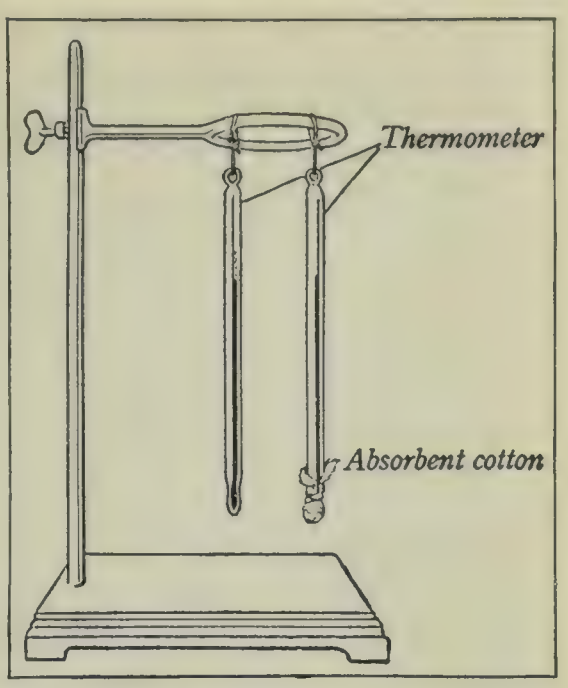


FIG. 162. A wet-bulb and dry-bulb hygrometer. If the air were saturated, both thermometers would read the same. Explain

Experiment 41. What is the relative humidity of the air in the schoolroom? Make a hygrometer thus: Suspend two thermometers side by side. Wrap the bulb of one with a very thin layer of absorbent cotton. Tie the cotton firmly in place with a thread or a string (Fig. 162). Moisten the cotton thoroughly.

TABLE FOR THE DETERMINATION OF RELATIVE HUMIDITY[1]

Dry Bulb	Difference between the Readings of Dry Bulb and Wet Bulb																
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°
15°	90	80	70	61	52	44	36	28	20	12								
16°	90	81	71	62	54	46	38	30	22	15	8							
17°	91	81	72	63	55	48	40	32	25	18	10							
18°	91	82	73	65	56	49	41	34	27	20	13							
19°	91	82	74	66	57	50	43	36	29	22	16	9						
20°	91	83	75	67	58	52	44	38	31	24	18	11						
21°	91	83	75	68	59	53	46	39	33	26	20	14	8					
22°	92	84	76	68	60	54	47	40	34	28	22	16	10					
23°	92	84	76	69	61	55	48	41	36	30	24	18	12	8				
24°	92	85	77	69	62	56	49	43	37	32	26	20	14	10				
25°	92	85	77	70	63	57	50	44	38	33	28	22	16	12	8			
26°	93	85	78	71	64	58	52	45	39	35	29	24	18	14	9			
27°	93	86	78	71	65	59	53	46	41	36	31	26	20	16	11			
28°	93	86	79	72	66	59	54	47	42	37	32	2	22	18	13	9		
29°	93	87	79	73	67	60	55	49	43	38	33	28	24	19	15	11		
30°	94	87	80	73	67	61	56	50	44	39	34	30	25	21	17	13	9	

[1] Values for rapid forced ventilation; temperatures in centigrade degrees.

Fan both thermometers vigorously. Note the temperature of each when it ceases to change temperature. Record the reading of each thermometer. Find the relative humidity of the room by means of one of the tables (on page 233 or page 247), thus: In the left-hand column find the temperature of the dry bulb. Then find the vertical column at the top of which is the number of degrees difference between the readings of the two thermometers. The relative humidity will then be the number (per cent) in this vertical column which is opposite the temperature of the dry bulb. Thus if the dry-bulb reading were 21° and the difference between the readings of the two thermometers were 6°, the relative humidity according to the table on page 233 would be 53 per cent. What is the relative humidity of the room?

Evaporation, temperature, and health. We have already learned that the body is cooled by the evaporation of perspiration or moisture from the skin. This constant cooling is necessary for health. In fact its lack may cause great discomfort, and in extreme cases may even cause death. In badly crowded rooms in which the air is not circulating, the air may become too humid; that is, it may contain too much moisture for good health. Our clothing prevents free circulation of air round our bodies. Hence, as perspiration evaporates from the skin, a hot blanket of moist air is formed next to our bodies. This layer of humid air interferes with further evaporation of perspiration and does not allow the skin to become cooled. If the air is kept in circulation, however, this humid air is removed and evaporation of perspiration from the skin takes place, using up much heat from the skin and thus making us comfortable.

To be most healthful, the air should have a relative humidity of from 50 to 70 per cent. In winter, however, there is usually too little moisture in the air inside the house. When the cold air from out of doors is warmed, its relative humidity may become as low as 20 per cent. This is actually drier than the air over a desert. The low relative humidity causes too rapid evaporation of perspiration from the skin, with the result that we become chilled, especially if there is a strong draft. Under these conditions we may think that the room is cold, though the thermometer may register 70° F.

Conditioned air. Conditioned air is now provided for public buildings, such as theaters and schools, for railway trains, and

to an increasing extent for houses (Fig. 163). Conditioned air is humidified successfully by spraying water or sending jets of steam into the air while it is being heated and before it is forced into the rooms. Its moisture content is also reduced if it is too humid.

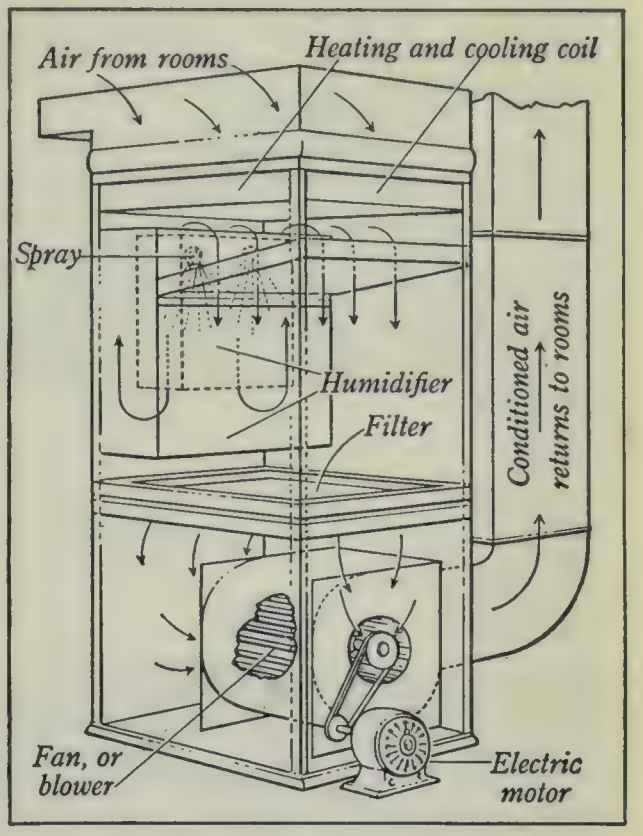


FIG. 163. A home humidifier. In winter, heated air is humidified by a spray of water. In summer the air is both cooled and made less humid by the cooling coil. Explain

Self-test on Problem XIII–B. (*Do not write in the book.*) 1. Precipitation results when the temperature of the atmosphere is *raised* to a temperature *above* its dew point.

2. Raising the temperature of air makes its relative humidity *greater*.

3. The greater the relative humidity the *less* rapid will be the evaporation of perspiration from the body, and therefore the more uncomfortably *cool* we feel.

4. If the air in a room is dry, one is likely to feel uncomfortably *warm* even though the temperature is relatively *high*.

5. Summer weather is likely to be uncomfortably *cool* if the humidity is *high* because there is *less* evaporation of perspiration from the body.

Problem XIII–C · What is the Relation of Humidity to Clouds and Precipitation?

Condensation and precipitation. We have learned that condensation of water vapor results whenever air is cooled to a temperature below its dew point. If the condensation takes place above the earth's surface, clouds are formed. If the condensation results in depositing water on the earth, the deposit of water is called precipitation.

U. S. Weather Bureau

FIG. 164. *A*, high stratus clouds above a low stratus cloud (fog bank). *B*, nimbus clouds above a fog bank. Can you see any evidence of wind in these pictures?

***Familiar cloud forms.** Clouds are composed of either minute drops of water or particles of ice, depending on whether the condensation takes place at a temperature above or below the freezing point of water, or 32° F. Clouds take many forms. The most common are stratus, nimbus, cumulus, and cirrus. Most of the other cloud forms are combinations of these. The form of the cloud depends chiefly on temperature and on air movements. When the air just above the earth is cooled so that the water vapor condenses on dust particles, fog results. Thus fog is a cloud resting on the ground. If the fog bank rises, it becomes a stratus cloud (Fig. 164, *A*). Stratus clouds are formed in nearly horizontal strata, or layers.

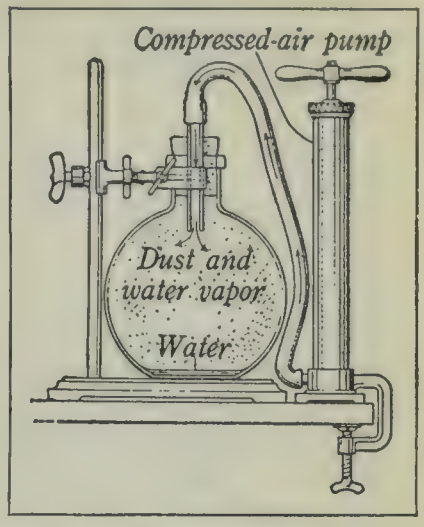


FIG. 165. Producing fog in a flask. **Exercise on Scientific Method (Inventing Experiments):** Why was dust or smoke introduced into the flask? Can you invent an experiment which will indicate whether or not the dust or the smoke was necessary in producing the fog?

Experiment 42. Can fog be produced in a flask? Pour a small amount of water into a flask. Put some chalk dust into the flask by tapping a dusty blackboard eraser against the top of the flask, or put smoke into the flask by dropping a lighted match inside. Close the bottle tightly with a one-hole rubber stopper (Fig. 165). Pump enough air into the bottle to blow out the cork. What do you observe in the flask? Can you explain what has occurred? Remember that when a gas such as air is compressed, it becomes warmer, and that when it is allowed to expand, it becomes cooler.

Nimbus clouds have no characteristic shape. They are thick dark masses with ragged edges torn by the wind (Fig. 164, *B*). Nimbus clouds are rarely over half a mile above the ground. When nimbus clouds appear, rainfall or snowfall may usually be expected. The thick, rolling, mountain-like masses are the cumulus clouds (Fig. 166, *A*). (Fig. 9, p. 19, and Fig. 158, p. 227, show other types of cumulus clouds.) They begin at an altitude of about two thousand feet and may extend more than four miles

Gayle Pickwell

FIG. 166. *A*, cumulus clouds; *B*, cirrus clouds. On a mountain top would one be likely to be above either of these forms of clouds? Explain

U. S. Weather Bureau

FIG. 167. Nacreous clouds. Why are these clouds always composed of ice particles?

above the earth. Their lower surfaces appear almost level. Their upper surfaces are like dome-topped mountains. This characteristic shape is believed to be due to ascending convection currents. The very high, white, flying cirrus clouds (Fig. 166, *B*) are thought to be flying masses of snow or sleet being carried along by the cold upper layers of air. They are usually five miles or more above the earth.

Unfamiliar cloud forms. Nacreous, or "mother-of-pearl," clouds showing rainbow tints are known to scientists (Fig. 167). These feathery ice clouds float in the stratosphere from fourteen to seventeen miles above the ground. Still more lofty clouds, the noctilucent ("shining by night") clouds, float in the stratosphere about fifty miles above the earth's surface. These, however, probably are not true clouds, since they are thought to be composed of fine dust instead of condensed water vapor. They have no rainbow tints.

Forms of precipitation. Common forms of precipitation are dew, frost, rain, snow, sleet, and hail (Fig. 168). Dew is of relatively little importance. It does not fall, as do other forms of precipitation. When objects become colder than the dew point of the air around them, some of the water vapor in this air condenses as dew on the surfaces of the objects (Fig. 161, *A*, p. 232).

Relations between the forms of precipitation. Frost is not frozen dew. If it were, it would consist of small round balls of ice. When the dew point of the air is below the freezing point of water (32° F.), vapor does not form water but instead forms crystals of frost as it condenses. Rain is formed in the same way as dew, only high above the earth rather than at the earth's surface. The vapor condenses as drops of water when the dew point is above freezing temperature. When the condensation, or condensing, of the vapor begins, the drops of water collect upon dust and smoke particles in the air, forming a cloud. If the condensation continues, the drops grow in size until they become heavy enough to fall to the ground as rain.

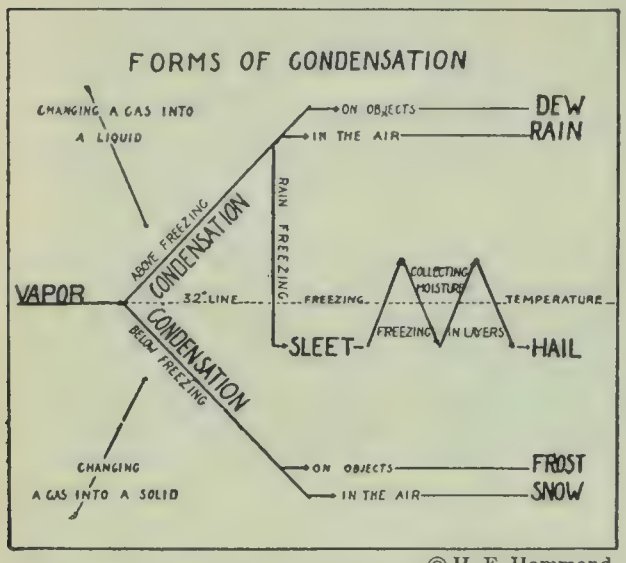


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FIG. 168. This diagram was planned and drawn by a student in a general-science class. Can you explain the diagram fully?

Snow is formed in the same way as frost. The vapor condenses at a temperature below freezing. Sleet is frozen rain. Sometimes the rain freezes as it falls. Sometimes, however, it freezes after it reaches the ground, coating objects with ice and causing great damage.

***Hail.** Hail usually forms in high clouds. The water condenses as rain and freezes, or condenses as snow which melts and then freezes again. These frozen drops grow larger as water continues to condense. If as they fall they enter strong convection currents upward, they may be carried upward again into the freezing air. Each time this happens another layer of ice is added to the outside. Hailstones two or three inches in diameter and consisting of several distinct layers have been found. Hailstorms are sometimes the cause of heavy damage to crops and to farm stock.

***Rain without rainfall.** We do not usually think of it as raining unless water is falling upon the earth. A very high cloud may

produce rain, snow, or even sleet, and this may fall until it comes into a lower stratum of dry and warm air, which may evaporate

FIG. 169. Map showing precipitation. In what regions is precipitation heaviest? lightest?

the precipitation without its having reached the earth. Particularly might this occur if the raindrops were as small as one fiftieth of an inch in diameter,[1] as sometimes is true. The largest raindrops, which may occasionally reach even one fifth of an inch in diameter, are less likely to be wholly evaporated before passing entirely through a layer of warm, dry air closer to the ground.

Cloudbursts. When precipitation occurs very rapidly it is sometimes called a cloudburst. A cloudburst may occur when the

[1] *Diameter* (di am'e ter): the longest distance across a circle.

FIG. 170. The water cycle. Can you explain this picture, using in your explanation these terms: *condenses, evaporates, rain, dew point, is cooled, heats, radiant heat energy from the sun, water, water vapor?*

air close to the earth is fully saturated and is cooled very suddenly. Cloudbursts are usually local.

Measuring precipitation. Precipitation is measured in inches (Fig. 169). Snow, hail, and rain are caught in instruments which measure and record the precipitation. The number of inches recorded is the number of inches that the depth of a pond would be increased if all the precipitation from directly above the pond were to fall into it and none were lost. Nine inches of snowfall equal about one inch of ordinary rainfall. Occasionally during a cloudburst six inches of water fall within a few minutes.

***The water cycle.** We have already learned that evaporation and condensation are opposite processes. When water is heated it evaporates in the form of water vapor. When water vapor is sufficiently cooled some of it condenses as water. The water of the earth is continually being evaporated and condensed. Thus for many millions of years the same water has been going through the water cycle[1] of evaporation and condensation (Fig. 170).

[1] *Cycle* (si'kl): a round, or series, of events or conditions which is continuously repeated.

Self-test on Problem XIII–C. (*Do not write in the book.*) 1. If the dew point is *above* the condensation point of water, the vapor condenses as ice or snow.

2. It would be *impossible* for dew to condense on the underside of a cold object.

3. Rain clouds are usually (1) stratus; (2) nacreous; (3) noctilucent; (4) cumulus; (5) nimbus.

4. The four common forms of clouds, in order from lowest to highest altitudes, are __(?)__, __(?)__, __(?)__, __(?)__.

5. Frozen rain falls as __(?)__ or __(?)__.

6. The rapid evaporation and condensation of water following each other in endless succession is called the water __(?)__.

Problem XIII–D · What is the Nature of the Work of the United States Weather Bureau?

Weather predictions.[1] There are few topics about which there are so many sayings, guesses, and superstitions as about the weather. The superstitions, the guesses, and many of the sayings are without foundation (Fig. 171). Some of the sayings, however, have more or less real observation to support them. When one says, " The rain crow (the yellow-billed or black-billed cuckoo, Fig. 386, p. 571) is singing, and that means that there'll be a rain before night," he is merely repeating an old superstition for which there is no known foundation. The saying " It rained on Saint Swithin's Day and will therefore rain on each of the forty following days" can be proved to be superstition merely by keeping careful records for a few years. Even if in one year it should rain in a certain place on forty successive days, records for added years would be needed before a rule could be stated.

A very different kind of saying from those just given is this: " There is a strong south wind, and therefore we shall probably have rain." There is considerable basis in facts for such a statement. Wind from the south is usually warm and humid. It is certain to be cooled somewhat as it travels northward. If this cooling is sufficient, there will be precipitation.

[1] *Prediction* (pre dik'shun): a prophecy about events that have not yet occurred. *Predict* (pre dikt'): to prophesy.

*Predictions concerning weather can be safely made only through a long-continued, scientific study of air pressures, temperatures, prevailing winds, and all other weather factors.

Ormal I. Sprungman

FIG. 171. It is sometimes said that if the ground hog (woodchuck) sees his shadow when he comes out of his hole on February 2, he goes back and there will be bad weather for six weeks longer. This is a silly superstition. Why? **Special Report:** How many other superstitions about the weather can you find?

***Service of the United States Weather Bureau.** The Weather Bureau of the United States is a division of the Department of Agriculture. It has made extended and detailed studies of the weather of the entire country as well as that of the surrounding countries and bodies of water. The Weather Bureau has established stations in the larger cities and also at other important points. From these stations the reports are telegraphed to the Washington office. Here the data are charted and the conditions and tendencies recorded. Very complete and detailed weather reports are then sent out by telegraph and radio all over the country. Newspapers print weather forecasts and reports. Weather maps (Fig. 172) are distributed by mail so that all who wish may know the weather that is likely to follow for the next day or so. Predictions are fairly accurate for two or three days during normal periods. They cannot be expected always to be accurate, since many unexpected factors may be introduced.

*This service from the Weather Bureau is of the greatest value and importance (Fig. 173). The farmer may learn whether the weather will be favorable to his plowing, planting, or harvesting.

The shipper may know whether to prepare his perishable goods for cold weather or for hot weather. The transportation company

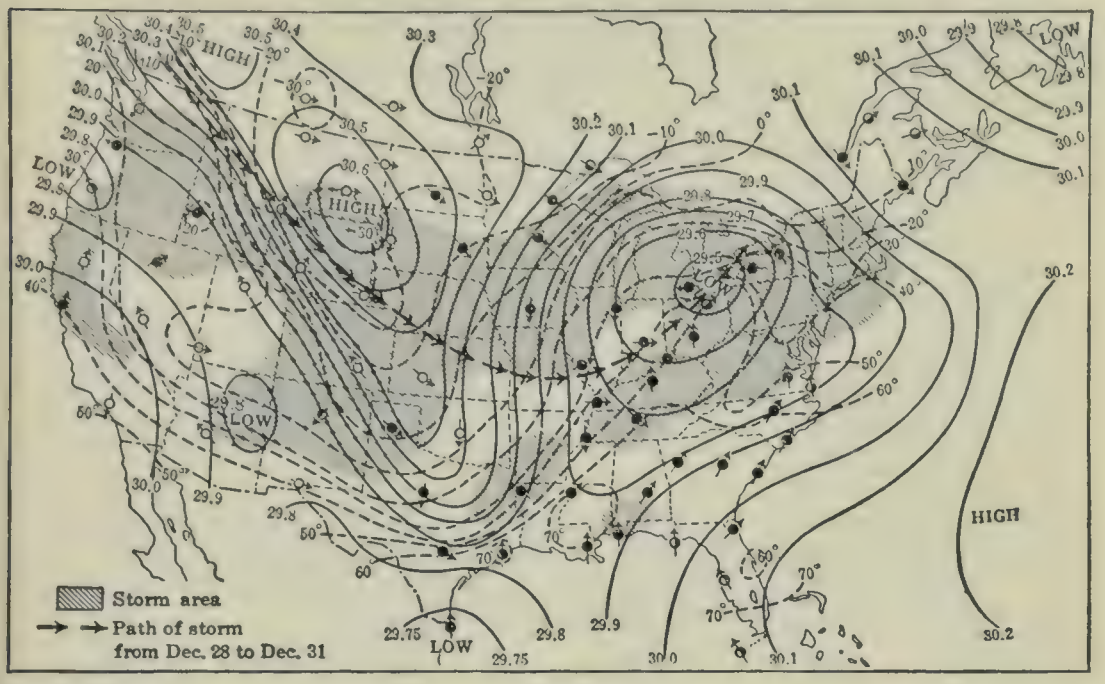


FIG. 172. Weather map for December 31, 1923. Note the positions and the shapes of the highs and the lows. The arrows show the path of the storm center after December 28. What were the weather conditions in the region of your home on December 31, 1923?

may know whether to expect rains, snows, or unfavorable temperatures along their routes. In river valleys flood conditions may usually be known long in advance of their arrival. Airplane journeys are planned after consulting the weather predictions. Many businesses — for example, the manufacture of ice cream and the sale of cooked foods — are influenced by weather predictions.

Reading a weather map. If you will refer to the weather map of the storm (Fig. 172), you will find that it gives much interesting and valuable information. The barometric pressures are marked on the curving black lines surrounding the centers of the highs and lows. The dotted lines up and down and across the country indicate places having the same temperatures, the little circles indicate how cloudy the weather was at various cities, and the arrows attached to the circles point in the direction toward which the wind was blowing in these cities. The shaded areas indicate precipitation.

FORECAST UNTIL 8 P.M. SATURDAY

For Detroit and Vicinity: Friday night unsettled with showers or thunderstorms and slightly warmer; Saturday unsettled in morning, possibly showers; fair in afternoon and cooler; fresh to possibly strong south to southwest winds.

For Lower Michigan: Showers and thunderstorms tonight and possibly Saturday morning; slightly warmer tonight in extreme east portion; cooler Saturday in west and south portion.

For the Upper Lakes: Fresh to probably strong shifting winds on Superior, mostly southerly shifting to northwest on Michigan, and southeast to south shifting to southwest on Huron tonight and Saturday; showers and thunderstorms except mostly fair Saturday on Michigan. Hoist southeast storm warning 9.00 A.M. Lake Superior east of Ashland and northern Huron and southwest warning on Michigan.

For the Lower Lakes: Increasing winds becoming fresh and possibly strong southeast to southwest by Saturday; unsettled weather with showers or thunderstorms on Ontario beginning tonight or Saturday and on Erie tonight and possibly Saturday.

FIG. 173. Part of the information sent out by the Detroit office of the Weather Bureau Friday morning, September 14, 1928. How many different kinds of business besides shipping would be benefited by the information given here?

Self-test on Problem XIII–D. (*Do not write in the book.*) **1.** In *most* cases weather sayings are based upon careful scientific observations.

2. The services of the United States Weather Bureau are of *little* importance to commerce and business.

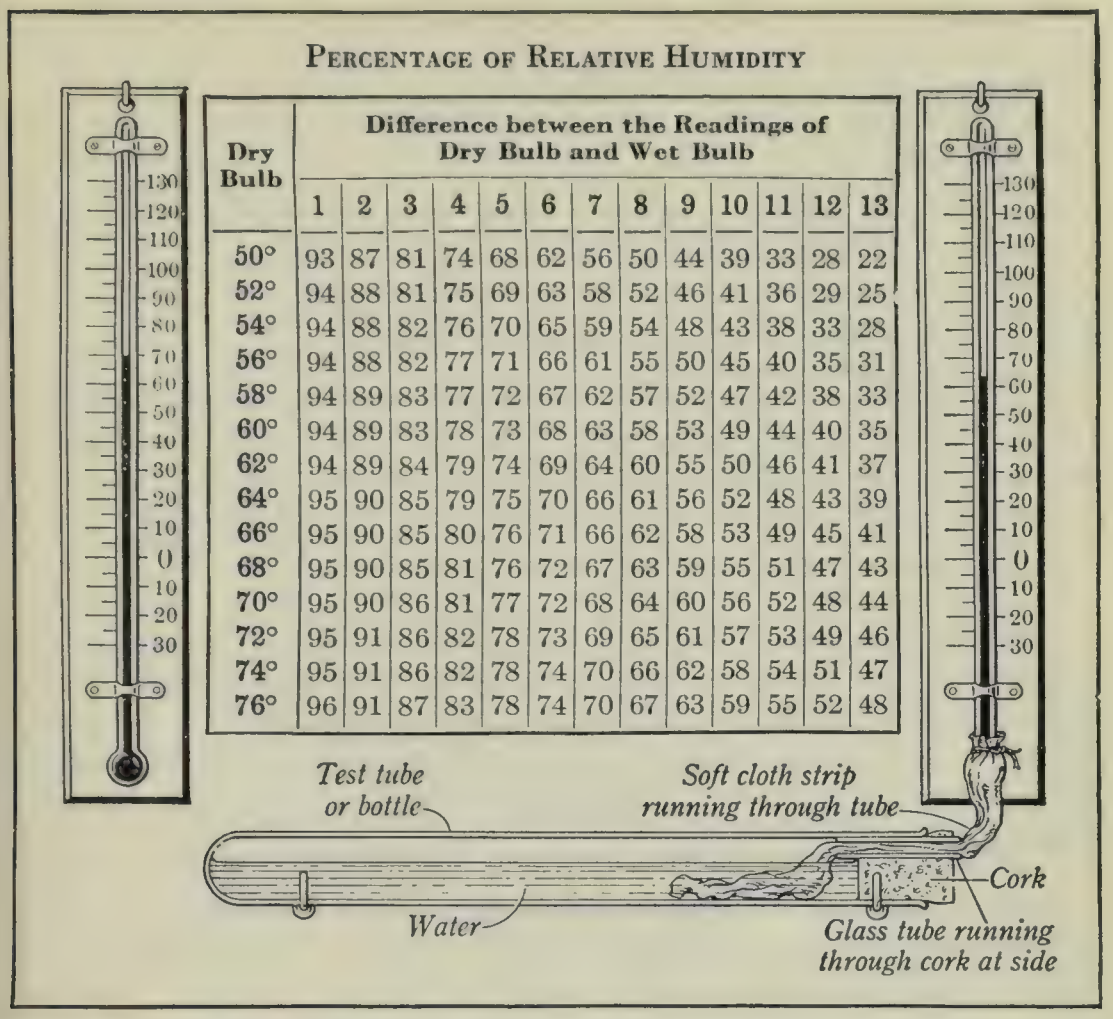
3. In *some* cases the predictions of the United States Weather Bureau are based upon scientific observations.

4. The main office of the United States Weather Bureau is in *New York City.*

Self-test on Scientific Principles. 1. What facts or principles of science which you have learned from preceding chapters would you use to explain or illustrate this principle: "The atmosphere of the earth prevents the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night is more than that gained during the day"?

2. How would you explain the following three statements to a boy or girl of your own age who has not studied science?

a. "The higher the temperature of the air, the greater is the amount of moisture required to saturate it."



PERCENTAGE OF RELATIVE HUMIDITY

Dry Bulb	Difference between the Readings of Dry Bulb and Wet Bulb												
	1	2	3	4	5	6	7	8	9	10	11	12	13
50°	93	87	81	74	68	62	56	50	44	39	33	28	22
52°	94	88	81	75	69	63	58	52	46	41	36	29	25
54°	94	88	82	76	70	65	59	54	48	43	38	33	28
56°	94	88	82	77	71	66	61	55	50	45	40	35	31
58°	94	89	83	77	72	67	62	57	52	47	42	38	33
60°	94	89	83	78	73	68	63	58	53	49	44	40	35
62°	94	89	84	79	74	69	64	60	55	50	46	41	37
64°	95	90	85	79	75	70	66	61	56	52	48	43	39
66°	95	90	85	80	76	71	66	62	58	53	49	45	41
68°	95	90	85	81	76	72	67	63	59	55	51	47	43
70°	95	90	86	81	77	72	68	64	60	56	52	48	44
72°	95	91	86	82	78	73	69	65	61	57	53	49	46
74°	95	91	86	82	78	74	70	66	62	58	54	51	47
76°	96	91	87	83	78	74	70	67	63	59	55	52	48

FIG. 174. A home-made hygrometer. The temperatures are in Fahrenheit degrees. Would the humidity readings with this hygrometer be too high or too low if the bottle were filled with alcohol instead of with water? Explain. (Designed by Lynn H. Clark)

b. "Differences in temperature cause differences in atmospheric pressure, and these differences in atmospheric pressure cause winds."

c. "Evaporation follows precipitation and precipitation follows evaporation in endless succession."

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is the surface of a flat hilltop likely to be hotter than the sloping sides of the hill?

2. It has been reported that there have been incidents when tadpoles, frogs, and fish have actually fallen from the air along with raindrops. Explain.

3. How would you explain or demonstrate to a boy or girl of your own age that dew does not actually fall?

4. From what direction do winds generally blow in the southeastern part of a low?

5. State two reasons why the temperature is generally lower in the eastern portion of a high than in the western portion.

6. Why do the windows of an automobile cloud over on the inside when one is driving in a closed car on a cold day?

7. In certain orchard regions "smoke pots" are kept ready among the rows of trees in case of threatened frost. At the first sign of falling temperature the smoke pots are lighted, and these produce a thick smoke blanket over the orchard. How does this help to prevent frost?

8. Why are icebergs frequently surrounded by fog?

Project. To make a home-made hygrometer. Fig. 174 shows such a hygrometer which was made at a cost of less than fifty cents. The two thermometers and the test tube are supported on a board large enough to afford room for the relative humidity chart to be pasted between the thermometers. The wet bulb should be fanned vigorously before a reading is taken.

Special Reports. 1. Ask your teacher to secure a weather map from the nearest office of the Weather Bureau. Find out how many kinds of information the weather map provides.

2. Ask your teacher to obtain a week's weather maps from the nearest office of the Weather Bureau. Make a study of the changes in weather at your home during the week, as shown on the map. Note the predictions made from day to day. How did these agree with the weather which followed them?

3. Tell in your own words the story of the typhoon described by Joseph Conrad in his very interesting book *Typhoon*.

4. What are waterspouts, where do they occur, and to what extent are they dangerous?

Books for Reference

HUMPHREYS, W. J. Weather Proverbs and Paradoxes. The Williams and Wilkins Company, Baltimore.

LAUGHTON, L. G. C., and HEDDON, V. Great Storms. Payson Publishing Co.

VAN CLEEF, E. Story of the Weather. D. Appleton-Century Company, Inc., New York.

Chapter XIV · Useful Knowledge about Climate

Questions this Chapter Answers

What is the distinction between weather and climate?
What conditions influence climate, and in what ways?
How do climatic conditions affect plants and animals?
How do climatic conditions affect human progress?

Problem XIV–A · What are the Factors that Influence Climate?

Differences between weather and climate. In common conversation the terms *weather* and *climate* are often used as if they meant the same. They do not. We have learned that the conditions from day to day with respect to temperature, air pressure, humidity, precipitation, clouds, and the winds make up the weather. The climate of any region is the average of these weather conditions over hundreds of years. The weather changes constantly from hour to hour, from day to day, and from month to month. Although many people believe that the climate also changes frequently, there is no change that can be noted in climate during a person's life. Such changes as are large enough to be noted occur only after centuries or even thousands of years (Fig. 175).

Climatic factors. It is a well-known fact that locations which are at about equal distances from the equator may have very different climates. Examples are Philadelphia (Pennsylvania) and Denver (Colorado); Tacoma (Washington) and Duluth (Minnesota); also Quebec (Quebec) and St. John's (Newfoundland). A number of factors are responsible for such climatic differences. Among these factors are prevailing winds, nearness to bodies of water, altitude (see Glossary), climatic winds, and the nature of the territory. We shall now consider some of these factors which influence climate.

***The great wind belts.** It is commonly known that the polar regions are cold. The earth receives more heat energy in the

J. A. Glenn and the New York State Museum

FIG. 175. This represents some kinds of animals that lived in the ocean which covered New York State at least two hundred twenty-five million years ago. **Exercise on Scientific Method (Inventing Hypotheses):** How many reasons can you think of which might account for the slow change from the scene pictured to the present New York climate?

regions near the equator than in the polar regions. If no other causes were involved, the air from the regions near the equator would always be forced upward by the colder polar air. In that case the winds near the earth's surface would always blow toward the equator and would be relatively cool, and the winds high above its surface would blow toward the poles and would be relatively warm. This tendency is in operation all the time, but instead of one great movement from poles to equator there are several wind movements which are generally recognized (Fig. 176). All of these, however, are affected and modified[1] by local conditions and by the constant shifting of local winds in response to changing weather.

[1] *Modify* (mod'i fy): to change or alter. *Modification* (mod i fi ka'shun): act or state of modifying.

If the earth did not rotate, the prevailing winds would blow north and south. Because of the earth's rotation, however, the

FIG. 176. Diagram showing the general wind directions in the great wind zones. Why are sailing ships frequently unable to make progress when they are near the equator?

prevailing winds blow in the general directions indicated in Fig. 176. These prevailing winds have important effects upon climate. Certain of them, especially the trade winds and the doldrums, have had an important influence on commerce. Because their force and direction near the earth are so nearly constant, these trade winds have been much used by sailing ships. The rate and movement of trade winds varies from ten to thirty miles per hour.

In the doldrums, or belt of equatorial calms, the air currents are generally rising. Here hot sultry weather, accompanied by local squalls,[1] thunder, and rain and by light uncertain and shift-

[1] *Squall:* a sudden violent wind accompanied by rain or snow.

Fig. 177. Lake and land breeze. The lake breeze or the sea breeze is usually stronger than the land breeze. Explain

ing winds, prevails. Sometimes sailing vessels move about in the doldrums for weeks. The sailors on such ships dread these calms.

Land and sea breezes. Land and sea breezes are local winds. They are important climatic factors along the shores of the Great Lakes and the oceans. Like all other winds, they result from convection currents. On a hot day the soil, the rocks, and the buildings of the land become heated more rapidly than does the water of lakes and oceans. The air above the land is expanded, and air from above the water flows in and crowds it upward. This is the cause of the sea breeze of the daytime (Fig. 177, *A*). At night, however, the direction of the wind is reversed (Fig. 177, *B*). The reason is that water loses its heat much less rapidly than land does. Hence at night the land breeze blows from the colder land toward the warmer water. Naturally the sea breezes are most extensive in summer weather and in hotter regions. They may affect the land surfaces to a distance of twenty-five miles or more from the bodies of water, but they are most noticeable within the first two or three miles. It is partly because of these air currents on the borders of bodies of land and water that such regions are sought as summer homes and places of recreation[1] in many countries.

[1] *Recreation* (rek re a'shun): pleasant pastimes which refresh mind and body.

FIG. 178. Grape farming in Italy. The vines are pruned and trained to grow upon the stem of a small tree. The branches of the supporting tree are cut back so that just enough grow to keep the tree alive, but not enough to shade the grapes. *A* is an early spring view. *B* is an autumn view with a full crop of grapes. This vineyard is as far north as are parts of Montana and North Dakota. Why can grapes be grown near the Mediterranean Sea better than in Montana and North Dakota?

Mountain and valley breezes, resulting from causes somewhat similar to those producing land and sea breezes, are common in mountainous regions.

***Effects of bodies of water on climate.** Large bodies of water, by acting as heat regulators, exert an important influence upon the climate of surrounding land. We have learned that water absorbs more heat energy for every degree its temperature is raised than does an equal weight of other substances. Consequently water gives off more heat energy in cooling a degree than does an equal weight of other substances. In hot weather, therefore, the water absorbs the heat without warming so rapidly as the shore. Also, in winter the water cools more slowly than the land, and as it cools it gives up its great stores of heat energy. Thus, by absorbing heat energy in summer and giving up heat energy in winter, bodies of water prevent extreme changes of temperature in the surrounding country. To illustrate these facts, in the Great Lakes region many cases are recorded where frost has occurred several miles from the lakes but not near them. The

water helps to keep the temperature above that at which frost occurs. Moreover, by changing temperature slowly, lakes and oceans have a marked influence in delaying near-by plant growth in springtime (Fig. 178). By thus delaying the flowering of fruit trees, they reduce the dangers to the plants from early frosts. By reducing the high temperatures in summer, bodies of water are of value to crops in reducing the excessive evaporation which extremely hot weather may cause.

The influence of great bodies of water in regulating temperature may extend for many miles from the shores. The moderating influence of bodies of water, however, may be modified by local climatic conditions. For example, the winds which generally blow from the north across the Great Lakes cause the northern shores to be colder than the southern shores. The moderating influences of bodies of water make the shores of lakes and oceans attractive as homes and for pleasure resorts during the summer.

Self-test on Problem XIV–A. (*Do not write in the book.*) **1.** Without doubt the climate in the part of the country where you live has changed *considerably* during the past few years.

2. Name the great wind belts of the earth.

3. In the material that follows can you fill each blank with either the word *land* or the word *water* so as to give a correct explanation of these breezes:

When the sun is shining upon the land and water the ___(?)___ heats more rapidly than the ___(?)___. The air above the ___(?)___ therefore heats more rapidly than the air above the ___(?)___. The air above the land therefore expands more rapidly than the air above the water. A partial vacuum, or reduced air pressure, is thus produced above the land. The greater air pressure over the ___(?)___ forces the colder air toward the ___(?)___. During the day, then, a breeze is blowing from the water to the land, and the convection currents over the land are being forced upward. At night, however, the land radiates its heat away faster than the water. Consequently the ___(?)___ becomes cooler than the ___(?)___. The air over the ___(?)___ cools faster than the air over the ___(?)___. The air over the land therefore contracts faster than the air over the water. The air pressure over the land consequently becomes greater than that over the water. At night, then, the greater air pressure over the ___(?)___ forces the air currents toward the, ___(?)___ causing the land breeze.

4. Winters are likely to be *more* severe and summers are likely to be *warmer* near great bodies of water.

FIG. 179. Mound at Arcola, Mississippi, a refuge for animals during the flood of the Mississippi River in May, 1927. Special Report: The nature and the extent of the destruction caused by floods

Problem XIV–B · How is Climate Related to Living Things?

Climatic conditions in relation to plants and animals. In the states of the upper Mississippi Valley the temperatures may range from 40° F. below zero on the coldest winter days to more than 100° F. on the hottest summer days. These extremes are not common, but they do occur. The range in precipitation may be from a period of many months with no rain to a month or more with daily rains (Fig. 179). A single rain may vary from the slightest trace of water to a cloudburst of an inch or more in a few minutes. How can plants and animals endure either the lowest temperatures or the highest? How can they live in the greatest dryness or the greatest wetness?

*Many of the simpler animals and many plants live a part of their lives in the form of cocoons or seeds, which can pass long periods of rest during cold weather. In this dormant[1] condition they may freeze and thaw many times without being killed, in case the temperature changes are brought about slowly.

[1] *Dormant* (dor'mant): in a prolonged period of rest without action.

B, J. R. Wilson

FIG. 180. *A*, well-watered vegetation; *B*, a desert view near Phoenix, Arizona. Could the plants in either environment survive in the other environment? Explain

*There are many structures and habits by means of which various animals endure the cold period or avoid it. Some animals, as birds and certain butterflies, migrate[1] to warmer regions before the coldest weather has come. Only man is able to endure practically every climate on the earth.

***Rainfall and vegetation.**[2] It is clear that a continued supply of water is needed not only by animals but by plants in their growing season. The total annual rainfall in various parts of the earth varies from a few inches a year to more than a hundred inches. Certain plants are able to live only where there is abundant rainfall. Others can live only where there is little rainfall. Thus, tropical[3] plants and those which live in or around lakes and

[1] *Migrate* (mi'grate): to go to a new home in a different region. When animals migrate they usually migrate back and forth as the seasons change. *Migration* (mi gra'shun): the journey made when animals migrate.

[2] *Vegetation* (vej e ta'shun): plant life of any sort.

[3] *Tropical* (trop'i kl): having to do with the tropics, or regions near the equator.

swamps are very different from desert plants (Fig. 180). Not only are desert plants able to get along with far less water than swamp plants, but many of them are able to store up the precious water in their bodies and to give it off from their surfaces and leaves very slowly.

*Climate, people, and progress. The people in the very hot or extremely cold climates have never made as great progress as have the people in the temperate climates. In the tropics heavy rainfall, high temperatures, and excessive humidity produce such an abundance of plant and animal life as to make it difficult for men to build cities and other works of civilization. There is food in plenty. But the great tropical forests, with their dense masses of trees, vines, and plants, and with their great number and variety of animals, many of them dangerous to man, cannot easily be conquered. Spaces in the jungles are cleared and kept clear with great difficulty, because the tropical vegetation grows so rapidly.

*In the coldest climates progress is held back, but for opposite reasons. Extremely low temperatures discourage life of all sorts. There is practically no life whatever at the poles. Where men are able to live in the polar regions the vegetation is scanty, with the result that fuel and food are scarce.

The leading industries and occupations of a region depend on climate (Fig. 181). Whether people shall engage in fishing, farming, fruit raising, grazing, logging, the running of health resorts, or the making of motion pictures is largely determined by the climate. Health is likewise influenced by climate. Mountain, desert, and certain coast regions are famous for their health resorts. Other regions are unhealthful for various reasons related to climate.

Altitude, people, and progress. In the world's history it has generally been found that the people who have lived either in very low land or in very high land have made much less progress than people who have lived at moderate heights above sea level. A reason is that the climate is likely to be less favorable to civilization in the extremely low or high altitudes than in the altitudes between these extremes. Progress is difficult or impossible in lowland swamps, in lowland valleys which are subject

A, W. S. Carlson; *B*, Keystone View

FIG. 181. *A*, an Eskimo girl cutting up a seal in Greenland; *B*, hauling coconuts in the Philippine Islands. Can you name characteristic occupations of your region which are possible only because of the climate which exists there?

to frequent floods, or in desert lowlands which are subject to long periods without rain. Progress is likewise difficult or impossible in the high mountainous regions, where the rocky hills and narrow valleys are usually unsuited to farming and to the building of cities. Moreover, in high altitudes the warm season is often too short for sufficient crops to grow or for sufficient necessities of other sorts to be produced or secured to enable people to live

comfortably during the long, severe winters. In the tropics, white people commonly find the lowland climate unsuited to them. When possible, therefore, they move to the plateaus which are high enough so that their climate is like that of the middle altitudes in the temperate zones, where progress has usually been most rapid.

Self-test on Problem XIV–B. (*Do not write in the book.*) 1. *No* animals and plants can live if frozen.

2. Desert plants can live where there is *no* water.

3. Man makes greatest progress in the *tropical* regions.

4. The climate of a region has *little* influence upon its industries.

5. Man makes greatest progress at *low* altitudes.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. It has been suggested as a possibility that another great lake might be made by damming the Red River of the North. If this were done, what would be the probable effect upon the winters in North Dakota?

2. Explain the causes of mountain and valley breezes.

3. Compare the good and the bad features of the climate in which you live.

Special Reports. 1. Secure records of annual precipitation in your region. Prepare a table and a graph showing the amount of precipitation for each month of the year.

2. Make a detailed study of a hot country: its location with reference to North America, Europe, and Asia; the trade routes by which it may be reached; the influence of its location upon its climate; its location with respect to prevailing winds; its position on the continent; its nearness to the ocean; its plant and animal life and how these are fitted for their environment; and the life, progress, and industries of its people.

3. Make a similar study of a cold country.

4. Discuss the conditions which exist in the belt of equatorial calms, as described in Joseph Conrad's very interesting story *The Mirror of the Sea.*

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Brooks, C. E. P. Climate. Charles Scribner's Sons, New York.
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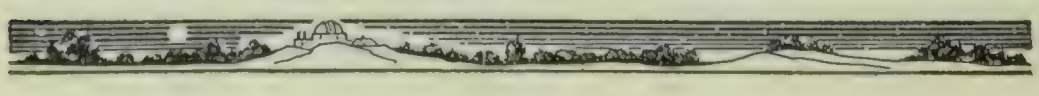
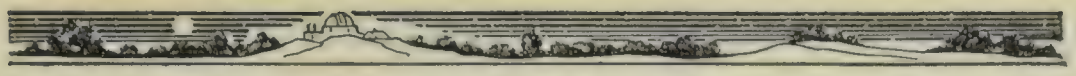
UNIT VI · *Into Space with the Astronomers*

PROBLEMS DISCUSSED IN THIS UNIT

The heavens have always been regarded with awe and wonder. History contains many incidents in which the heavenly bodies have influenced what men thought and did. In the third century B.C. a Greek philosopher named Aristarchus announced his belief that the earth and planets move about a central fire, the sun. This belief was considered wicked, because it did not agree with the religious teachings of that time. In a still earlier time, 585 B.C., while a battle was in progress between the Medes and the Lydians, there occurred a total eclipse of the sun. The soldiers were so frightened that they ceased fighting, and their leaders made a lasting peace. Then in the fifteenth century, when the Turkish armies were invading Europe, a comet appeared like a great Turkish sword of fire in the sky. The European forces, believing the comet to be a sign of coming disaster, prayed, "From the Turk and the comet, good Lord, deliver us." In 1610 Galileo, the famous Italian scientist, made a crude telescope with the help of which he was the first man in the world to see four of the moons of the planet Jupiter and the mountains of the moon. For these and other scientific discoveries Galileo was thought to be crazy or very wicked. From that day to the present, telescopes have been steadily improved, and some now under construction will enable men to extend their view into space thousands of billions of miles farther than is now possible. This unit deals with these problems relating to astronomy:

How has astronomy developed?
What is the nature of space and of the stars in it?
What are the characteristics of the solar system and of bodies which compose it?
What are the phenomena connected with the moon's movements?
How does the energy of the tides result from the moon and sun?
What causes the seasons?
How are time and location determined?





Chapter XV · Beyond the Earth

Questions this Chapter Answers

How did astronomy grow out of astrology?
What recent inventions have made possible great advances in astronomy?
How vast is space?
What are the characteristics of the suns, or stars?
What are the characteristics of galaxies?
How important as a heavenly body is the earth?

Problem XV–A · How has Astronomy Developed?

***The beginnings of astronomy.** Even the first men must have studied the skies. They needed to know something about the heavens in order to survive. They had to judge time by the positions of the sun during the day and of the moon and stars at night. They had to watch the sky to know when it was wise to plant and reap their crops, and when it was safe to go on hunting and fishing expeditions.

Since so much of their safety and welfare depended upon being able to observe and interpret the positions of the heavenly bodies, primitive men came to regard the heavens with awe and superstition. It is easy to understand how sun worship became an important part of the religions of many ancient peoples.

Astrology. Little by little, as men became civilized, they began to organize their scanty knowledge of the heavens into a rude kind of science. This was not at first a real science of astronomy,[1] because such astronomical facts as were then known were mixed with all sorts of superstitious beliefs. This mixture of a little astronomy with a great deal of superstition and fancy was called astrology.

[1] *Astronomy* (as tron'o my): the science of the stars and other bodies in the heavens. *Astronomer* (as tron'o mer): one who has a broad and exact knowledge of astronomy. *Astronomical* (as tro nom'i kl): having to do with astronomy.

Astrology was well established in the days of ancient Babylon, about 3000 B.C. It spread from Babylon throughout the ancient world. The ancient astrologers were priests who pretended to be able, by studying the positions of the planets and stars, to predict the will and intention of their gods.

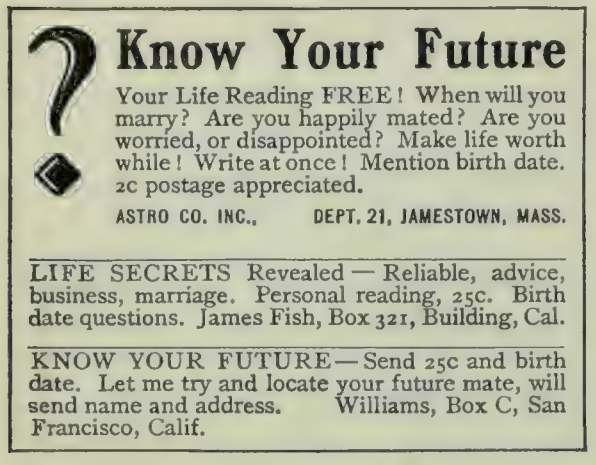

Know Your Future
Your Life Reading FREE! When will you marry? Are you happily mated? Are you worried, or disappointed? Make life worth while! Write at once! Mention birth date. 2c postage appreciated.
ASTRO CO. INC., DEPT. 21, JAMESTOWN, MASS.
LIFE SECRETS Revealed — Reliable, advice, business, marriage. Personal reading, 25c. Birth date questions. James Fish, Box 321, Building, Cal.
KNOW YOUR FUTURE — Send 25c and birth date. Let me try and locate your future mate, will send name and address. Williams, Box C, San Francisco, Calif.

FIG. 182. Advertisements of astrologers. **Special Report:** The influence of Martius Galeotti, the astrologer, over Louis XI of France, as described in Scott's *Quentin Durward*

The most intelligent people have long ceased to believe in astrology or even to regard it as a science. Yet today we still occasionally find persons who claim that they are astrologers. They claim to be able to study the stars and the planets and thus to be able to tell one's "past, present, and future, to advise in love, marriage, and business," and to do other impossible things (Fig. 182). Most people who make such claims are "quacks," who prey upon the superstitions and ignorance of other people.

Astrology and astronomy. The science of astronomy owes much to the early astrologers. In their study of the sky for omens or signs bearing upon human affairs, they discovered and confirmed many scientific facts. Thus astronomy slowly developed out of astrology.

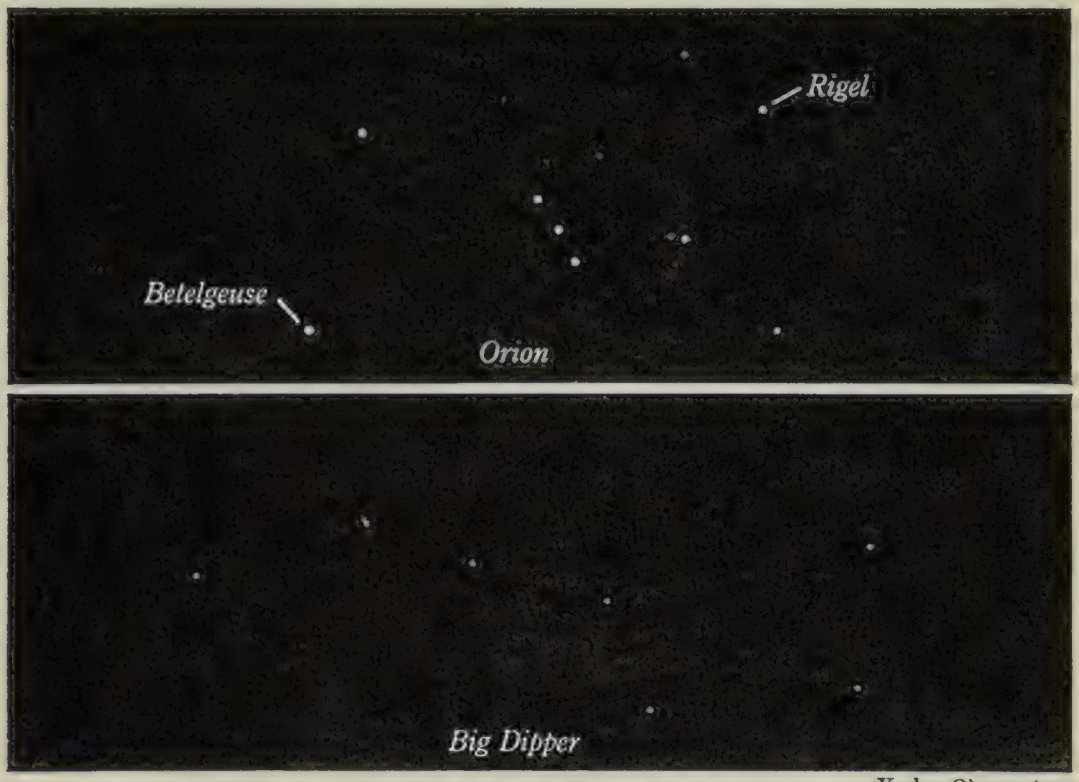
Many hundreds of years before the time of Christ, the Babylonians and other ancient peoples had learned to recognize five of the planets — Mercury, Venus, Mars, Jupiter, and Saturn — and had given names to the most conspicuous of the constellations. But the Greeks receive credit for having made the beginnings of a real science of astronomy, because they were the first people who tried to classify[1] the heavenly bodies and to explain the astronomical facts they found in the writings of the Egyptians, Chaldeans, and other ancient peoples.

[1] *Classify* (clas'i fy): to arrange objects or facts in classes; to put into classes.

Two Familiar Constellations

BETELGEUSE and Rigel are two first-magnitude stars. The Big Dipper is part of the Great Bear. The two stars in the front of the bowl of the dipper point toward the Pole Star. The ancient Greeks invented myths or stories to try to explain the constellations. Here is one:

Jupiter, king of the gods, fell in love with Callisto, a nymph. Juno, queen of the gods and wife of Jupiter, became jealous of Callisto and determined to



Yerkes Observatory

FIG. 183. Does the Big Dipper still remain always above the horizon?

destroy her. In order to save Callisto's life, Jupiter changed her into a bear. Juno then plotted to have Diana kill the bear in the chase. To save her, Jupiter placed the bear, Callisto, in the heavens, and near her he placed her son, Arcas, as the Little Bear. When Juno learned of the honor which had been bestowed upon Callisto and Arcas, she was more angry than ever. In her desire for revenge she hastened to Oceanus, king of the ocean, and persuaded him never to allow the nymph and her son to set in the ocean like the other stars. Therefore the Great Bear and the Little Bear must always keep turning round and round the night sky without rest (above the horizon).

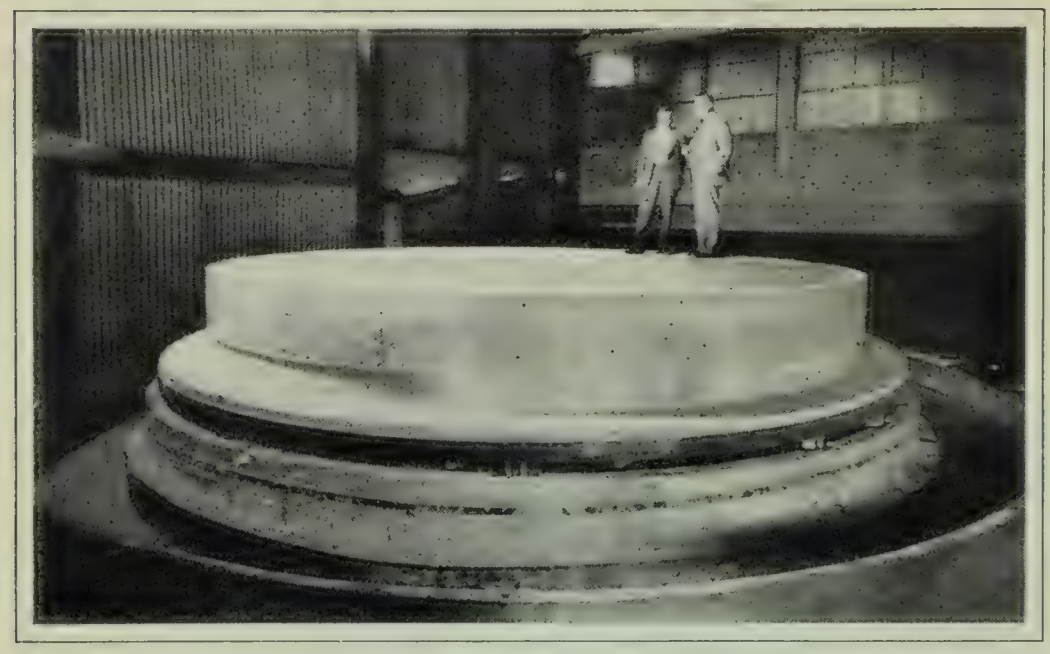


FIG. 184. The glass disk from which will be made the 200-inch reflecting mirror of the great telescope of the California Institute of Technology observatory at Palomar Mountain near San Diego. The disk had to cool slowly for months to prevent its cracking. Why would sudden cooling cause it to crack? Sometimes during the long period of cooling portions of the glass crystallize, or form crystals, with the result that an entire new disk has to be cast

The Greeks named many of the constellations (Fig. 183) after their gods, their heroes, and various animals and creatures of their imagination. Many interesting myths[1] and legends, which attempted to explain and account for the constellations, have come down to us from the ancient Greeks (see page 263).

Progress in astronomy. It is surprising how much the early astronomers learned when we remember that they had to make all their observations with the naked eye. The telescope was invented only about three hundred years ago, and the spectroscope is a very recent invention. By means of the telescope (Fig. 184), the spectroscope, and other marvelous instruments, astronomers have been able to measure the distances to various stars, to find out the nature and the weight of the earth, the sun, and other heavenly bodies, and to determine much about the conditions which exist on the different planets.

[1] *Myth* (mith): a story invented to explain some phenomenon or custom.

Self-test on Problem XV–A. (*Do not write in the book.*) 1. Astronomy grew out of __(?)__, which is not a true __(?)__.

2. The statements of astrologers concerning what will happen in the future are very *likely* to come true.

3. The beginnings of scientific astronomy were made by the __(?)__.

4. Name two instruments of great value in the study of astronomy.

Problem XV–B · What is the Nature of Space and of the Stars in It?

The extent of space. The sun, the earth, the stars, and all the other heavenly bodies are in an enormous vacuum called space. The extent of space is so great that we cannot comprehend it. A few facts, however, will help us to understand how vast space is.

If an express train could leave the sun and travel without stopping at the rate of a mile a minute toward Mercury, the planet nearest to the sun, it could not reach Mercury for nearly seventy years. It would take the same train nearly seven thousand years to travel from the sun to Pluto, the planet farthest from the sun. Yet, vast as our solar system[1] is, it occupies only an exceedingly small part of the space which the astronomers have explored. In fact, between our sun and the next nearest star there would be room for several thousand solar systems as large as ours. Other stars are known to be no less than twenty thousand times as far away from our sun as is the nearest star.

We can get an idea of the enormous distances in space in another way. Light travels about 186,000 miles in one second. Thus it travels fast enough to go around the earth at the equator more than seven times in one second. It takes the light and heat from our sun about eight minutes to travel by radiation from the sun to the earth. It takes over four years for the light to travel to us from Alpha Centauri, the star nearest to our sun. The light that we are now receiving from the polestar left that star about 286 years ago, and there are stars so far away that the light by which we now observe them started from them nearly a hundred thousand years ago. If they should be destroyed, we should have

[1] *Solar* (so'lar): having to do with the sun. *Solar system:* the sun and all the bodies which circle around the sun.

no way of knowing this for thousands of years, for the light that left them before they were destroyed would still be coming to us.

Large and small suns. The astronomers have learned that the stars or suns vary greatly in size. Some suns are no larger than the planets of the solar system. Our sun is more than a million times larger than the earth. Betelgeuse,[1] the beautiful orange-red star in Orion,[2] has about twenty-seven million times the volume of our sun, and red Antares[3] may be a still larger sun.

Most of the suns are too hot to be anything but gas. Antares is less dense than the best vacuum which we can make in the physics laboratory. Antares is a gas so light that it is less than one millionth as dense as water, that is, one millionth as heavy as a globe of water of the same size would be. Our sun is one and a half times as dense as water. Some of the smallest suns are many thousand times as dense as water — so dense, in fact, that a cubic inch of their substance would weigh a ton. Yet they are not solids, but behave like gases. They are so dense, however, that it would take a powerful derrick to lift a lump of this substance the size of a golf ball; and a railroad flatcar could hardly hold up the weight of a lump the size of a man's doubled fists!

The Milky Way. When we look at the sky on a clear night when the moon is not shining, we see a broad band of dim light stretching across the heavens. We call this band of light the Milky Way, or Galaxy. When we examine the Galaxy with a small telescope we find that the dim light is really the light of separate stars which appear so close together that we cannot see them as separate stars with the naked eye. A small telescope reveals several hundred thousand stars in the Galaxy, while with the great modern telescopes more than a billion[4] have been photographed (Fig. 185). Astronomers believe that there are probably innumerable suns in our Galaxy which even the largest telescope does not reveal, because their light is too dim or because they are dark. Doubtless hundreds of thousands more would be revealed by still more powerful telescopes.

[1] *Betelgeuse* (be'tl jooz): one of the largest stars, or suns.
[2] *Orion* (o ri'on): a constellation named for a giant hunter in a Greek myth.
[3] *Antares* (an ta'reez): one of the largest stars, or suns.
[4] *Billion* (bil'yun): a thousand million.

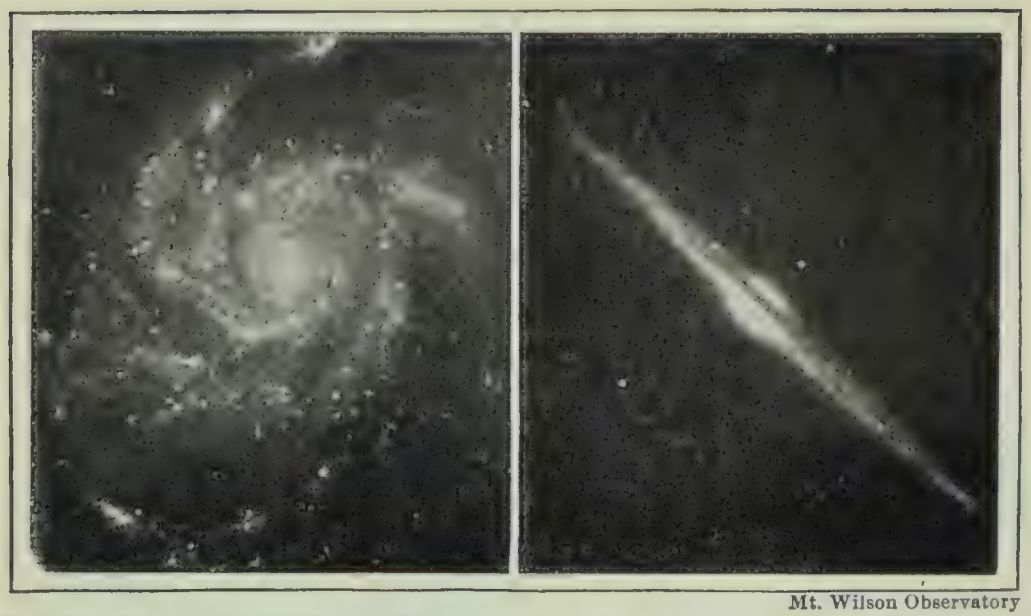
Motion and gravitational energy. Astronomers know that our sun is merely one of the medium-sized stars in the Galaxy. If the whole Galaxy could be seen at once, it would be found to be an enormous swarm of suns grouped together somewhat in the shape of a watchcase (Fig. 186). All these suns are moving in response to the gravitational attraction of other stars in the group. They are traveling in various directions as does a swarm of insects, at the average rate of about half a billion miles a year. They are so far away that from year to year and even from century to century we can observe practically no changes in their positions; in fact, if we could have seen the sky at the time when the most ancient astronomers lived, it would have looked almost exactly as it does now.

Yerkes Observatory

FIG. 185. Star clouds in the Milky Way. Every white dot is a sun. These suns are trillions (millions of millions) of miles apart. **Special Report:** The astronomical work of Newton and of Galileo

Many galaxies in the heavens. The Galaxy which we see in the sky is brighter than other portions of the heavens, because we are looking through that part of it which is greatest in extent and where the stars are thickest. Moreover, these stars are not close together, as they seem to be. They are, in fact, thousands of billions of miles apart. Furthermore, the Galaxy of which our sun is an ordinary member is only one swarm of stars. There are hundreds of thousands of luminous [1] cloudy patches called spiral nebulae (Fig. 186) scattered throughout the heavens. Many of these are distant galaxies containing billions of suns. Some of these galaxies are probably smaller than ours, and others may be even larger.

[1] *Luminous* (lu'mi nus): giving off light.



Mt. Wilson Observatory

FIG. 186. Two spiral nebulae. The second has its edge toward us. If it could be seen from the front, it would doubtless look much like the first. **Special Report:** Dark nebulae. (Consult an encyclopedia or a textbook of astronomy)

Our earth of small importance in the heavens. Our earth seems to us vast and important. However, it is just a tiny speck in comparison with our sun, which is only a medium-sized star estimated to be merely one of perhaps ten billion in the Galaxy. There are, moreover, about seventy-five million other galaxies, or star systems, scattered through space. These are enormous distances apart; in fact, those nearest each other are separated by probably a million light years.[1] We are forced to realize that our earth and ourselves and even our solar system are so small as to seem of little importance. Yet we can be proud of the fact that, small as we are, the minds of our scientists have been able to invent instruments which have enabled them to explore these vast heavens and to tell us with assurance about so many of the marvels that the heavens contain.

Self-test on Problem XV–B. (*Do not write in the book.*) **1.** Our solar system occupies a very *large* portion of the heavens.

2. The star nearest the earth is __(?)__.

3. Light travels at a speed of about __(?)__ per __(?)__.

[1] A light year is the distance light would travel in one year at the rate of 186,000 miles per second, or about 5,866,000,000,000 miles.

4. Our sun is a *large* star.

5. The Milky Way, or Galaxy, is probably composed of *many millions* of suns.

6. The movements of the stars are due to _ _(?)_ _.

ADDITIONAL EXERCISES AND ACTIVITIES

Exercise on Scientific Attitudes. A teacher of general science asked this question in an examination: "Give two reasons why you believe the earth is round." One pupil wrote, "I believe the earth is round because you told us it is, and because the book says so, too." Which of the statements that follow would a scientist choose as best? Justify your answer by stating one or more of the scientific attitudes (pp. 12 and 13).

a. The pupil's reasons were poor, because he had not found out the reasons why the teacher and the book said the earth is round.

b. His reasons were good, because teachers of science seldom make mistakes and books never do.

c. His reasons were poor, because he should have tried to find out for himself by experimenting whether the earth is round.

d. His reasons were poor, because both the teacher and the book might have made a mistake.

e. His reasons were good, because teachers of science and books on science are usually correct.

Special Reports. **1.** What astronomical knowledge was possessed by the Egyptians? the Chaldeans? the Babylonians? the ancient Chinese? (Consult an encyclopedia or a history of astronomy.)

2. Where are the greatest telescopes of the world located? How large is each? Describe one of them.

3. What are the characteristics of some of the great stars of the first magnitude? (Consult a textbook of astronomy.)

4. Secure an almanac and make a report on any astrological material in it. How would you proceed to convince somebody else of the unscientific nature of astrology?

5. Look up the meaning of *pseudo* in a big dictionary. Can you explain this statement: "Astrology is a pseudo science"?

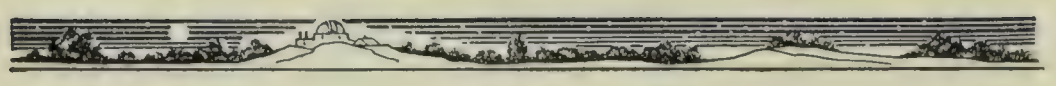
Books for Reference

BARTON, S. G. and W. H. A Guide to the Constellations. McGraw-Hill Book Company, Inc., New York.

HOWE, H. A. The Elements of Descriptive Astronomy. Silver, Burdett and Company, New York.

LUKIESH, A. A Book of the Sky. E. P. Dutton & Co., Inc., New York.

OLCOTT, W. T. A Field Book of the Stars. G. P. Putnam's Sons, New York.



Chapter XVI · The Solar System

Questions this Chapter Answers

What are the characteristics of the solar system?
What are the characteristics of the sun?
What are the characteristics of the nine planets of the solar system?
Are there people on Mars?
What and where are the asteroids?
What are comets, meteors, and meteorites?

Problem XVI–A · What are the General Features of the Solar System?

***What "solar system" means.** Our solar system consists of our sun and all the heavenly bodies of various kinds that revolve round it. These bodies are the nine planets with their satellites (moons), the asteroids (sometimes called planetoids), the meteors and meteorites, and the comets.

*Each of these bodies follows an orbit, or path, round the sun or some other body. Each is held in its orbit by gravitational attraction, which tends to pull it in toward the sun. If it were not for this attraction the centrifugal force (inertia) of the swiftly moving planets would cause them to travel straight away, never to return. These orbits are so exact and definite that after a few observations of a planet, moon, asteroid, or comet the astronomers are able to compute the entire orbit of the body and to determine with great accuracy where that body will be at any future date.

Experiment 43. What is the shape of a planet's orbit? Through the middle of an old rubber ball or tennis ball stick a darning needle just a little longer than the diameter of the ball (Fig. 187). Make a rubber string two or three feet long by tying rubber bands together or by doubling a section of the rubber winding of the core of a golf ball. Wind this string *tightly* round the ends of the needle back and forth several times, leaving the end of the string projecting from the middle of the ball between the ends of the needle. The ball represents a planet. Whirl the ball round your head. Note the shape of the path

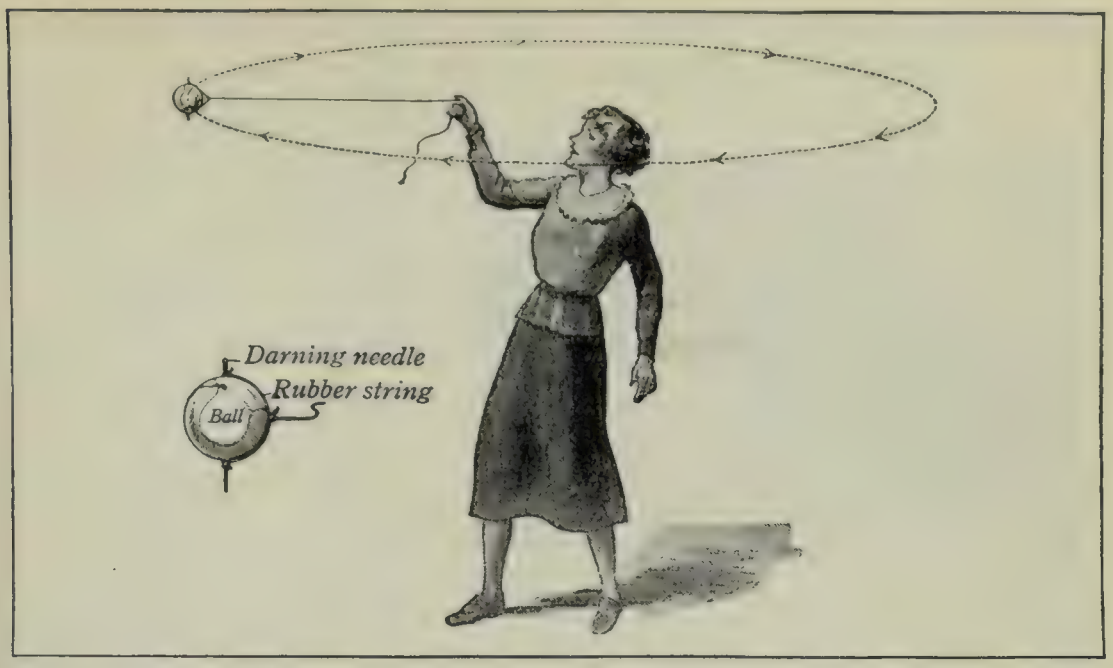


FIG. 187. Special Reports: Orbits that are not circular. (Consult an encyclopedia or big dictionary)

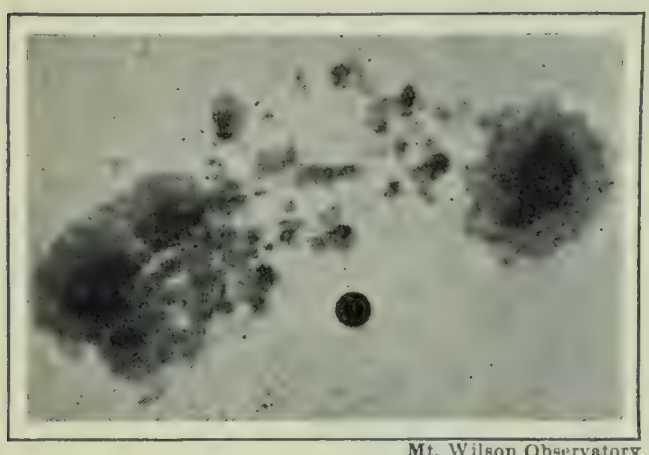
or orbit when you make it go faster in one part of its orbit than in another. Answer with a complete sentence the question asked at the beginning of this experiment.

Characteristics of the sun. The sun is a yellow star. It is a ball of incandescent gas about 865,000 miles in diameter, or somewhat more than a million times as large as the earth. It is about 93,000,000 miles from the earth, or nearly four hundred times as far away as the moon is from the earth. It rotates (spins on its axis[1]) faster at the equator than near the poles, requiring about twenty-five days at the equator and about thirty days near the poles. The temperature at its surface is as high as 10,000° F., which is much greater than any temperature that has yet been produced on the earth. It is believed that toward the middle of the sun the temperature is enormously hotter than at the surface. It is also believed that this inner heat causes explosions which appear to us as the sunspots. Around the sun is an atmosphere of incandescent gases many thousands of miles deep.

Energy of the sun. As we observe the sun through a powerful telescope we see dark spots here and there. These range from a

[1] *Axis* (ax'is): the line which is imagined as passing through a spinning body and upon which the body rotates or turns.

few miles to many thousands of miles across. They are called sunspots (Fig. 188). Sunspots are violent storms that resemble enormous tornadoes, and are probably caused by eruptions[1] from beneath the sun's surface. Sunspots may disappear in a few days or they may last for months. We find other evidence of storms on the sun. Masses of matter many times larger in volume than our earth are blown across the face of the sun at a rate of hundreds of miles a minute as if by a violent wind. As we watch we see other equally vast masses of matter hurled upward hundreds of thousands of miles away from the surface as if by the energy of extremely violent explosions (Fig. 189).



Mt. Wilson Observatory

FIG. 188. A group of sunspots. The round black spot is drawn in the photograph to show the size of the earth compared with these sunspots. About how many times as great as the diameter of the earth is the large sunspot at the right?

All the energy which the earth receives from the sun is only about one part in every two billion of the energy which the sun is constantly radiating off into space. Yet without this energy life on the earth would be impossible, for we should have no green plants and consequently no food. Moreover, without this exceedingly small portion of the sun's radiant energy there would be no winds and no rains and consequently no rivers and streams.

Yerkes Observatory

FIG. 189. This explosion at the sun's surface is called "Woolly Elephant" because of its shape. The earth would look like a small dot beside this prominence. Special Report: How are astronomical photographs taken? (Consult an encyclopedia or a textbook of astronomy)

[1] *Eruption* (e rup'shun): a violent pouring out of matter, as from a volcano.

Of what is the sun composed? A study of the sun through a spectroscope shows that it is made up of many of the elements found on the earth. In fact, the elements which are most abundant on the earth are also most abundant in the sun, the stars, and the nebulae. The nature of nearly sixty of these solar elements has been determined. These are chiefly hydrogen, helium, oxygen, carbon, nitrogen, iron, and certain other metals. All, however, are in a gaseous state. No gold, platinum, or mercury has yet been discovered in the sun. Nevertheless these heavier elements may exist there, but so far inside that light from them does not reach the sun's surface.

Self-test on Problem XVI–A. (*Do not write in the book.*) **1.** The planets and other bodies in the solar system are held in their orbits by (1) gravitational attraction; (2) energy; (3) weight; (4) inertia; (5) centrifugal force.

2. In the following list of bodies, which ones are parts of the solar system: comets, asteroids, planetoids, satellites, moons, nebulae, sun, Alpha Centauri, meteorites, meteors?

3. The sun is more than a _ _(?)_ _ times as big as the earth and is nearly _ _(?)_ _ times as far away as the moon is from the earth.

4. The earth receives a *very large* part of the sun's radiant energy.

5. *Most* of the elements which compose the sun are found on the earth.

6. *Less* than half the elements which compose the earth are found in the sun.

Problem XVI–B · What are the Characteristics of the Smaller Planets?

Few suns have planets. Astronomers have never yet found any evidence which would lead them to believe that any other star besides our sun is surrounded by a group of planets. In fact, there are reasons to believe that if there are any other suns surrounded by planets, those suns must be exceedingly rare. Furthermore, we have no way of discovering any of these planets if they do exist, because if a planet as great as Jupiter, the largest in our solar system, circled round the nearest star beyond our sun, it could not be seen with the most powerful telescope yet designed.

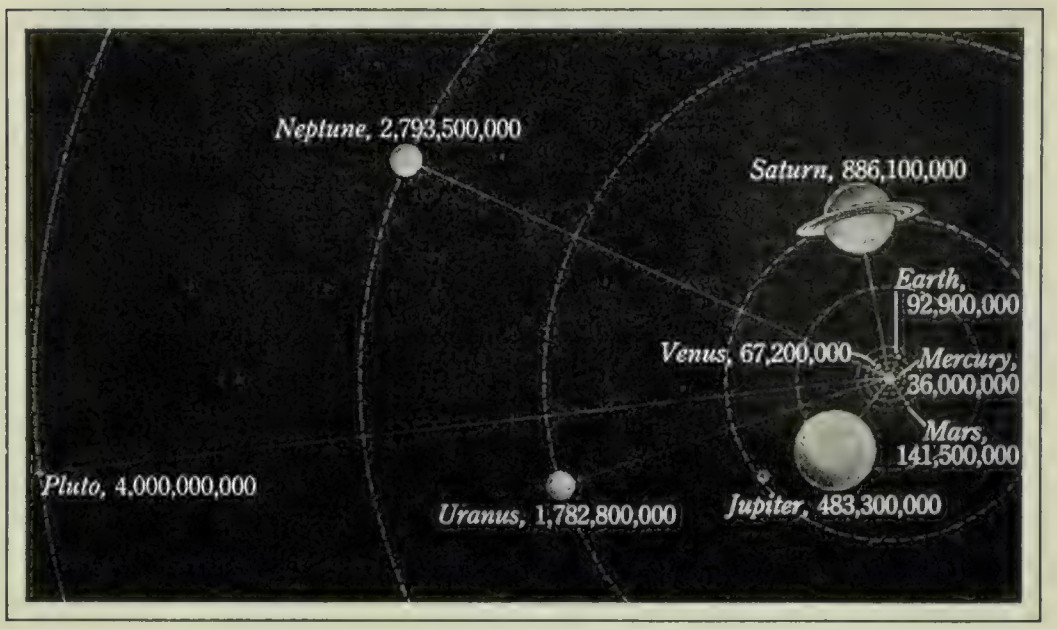


FIG. 190. Diagram showing the relative sizes of the planets and their relative distances from the sun. How do you account for the fact that the ancients discovered Mercury, Venus, Mars, Jupiter, and Saturn?

	Average Diameter, in Miles	Revolution around Sun, in Years
Mercury	3,030	.24
Venus	7,700	.62
Earth	7,918	1.00
Mars	4,230	1.88
Jupiter	86,500	11.86
Saturn	73,000	29.46
Uranus	31,900	84.02
Neptune	34,800	164.78
Pluto	5,500	247.69

*The planets. There are nine planets known in our solar system (Fig. 190). They may be distinguished from the stars because (1) they shine with a steadier light and (2) from night to night they change their positions among the stars. We can see them because, like the moon, they reflect the sunlight. Named in the order of their distances from the sun, they are Mercury, Venus, the earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The four nearest the sun are called the terrestrial planets. The next four in order of distance from the sun are called the

great planets. The terrestrial planets are small, solid, and several times denser than water. The great planets are many times larger than the terrestrial planets (Fig. 190), and probably all of them are largely gaseous. Jupiter, Uranus, and Neptune are denser than water, but Saturn is less dense; that is, it would float if there were an ocean of water big enough to hold it. Pluto is probably like the terrestrial planets. None of the planets is a perfect sphere. All are slightly flattened at the poles — the great planets more so than the terrestrial, and Saturn most of all. All follow definite paths, or orbits, round the sun. All travel in their orbits from west to east. Their orbits are almost perfect circles, that of Neptune being most nearly perfect, and are all in nearly the same plane.

The earth, Mars, Jupiter, and Saturn rotate in the same direction in which they revolve round the sun — from west to east. Uranus rotates almost at right angles to the plane of its orbit and slightly from east to west. Mercury and Venus are the only planets which have not at least one satellite, or moon. Nearly all the other planets have more than one moon.

Some astronomers believe it possible that there may be still other planets which revolve round our sun, but at distances so great that they have not yet been discovered.

Relative sizes and distances in the solar system. It will help you to get a mind picture of the solar system if you think of the sun as a ball five feet in diameter. On this same scale, then, Mercury would be represented by a tiny ball about one fifth of an inch in diameter, over 200 feet from our five-foot sun; Venus, by a marble about half an inch in diameter, nearly 380 feet away; the earth, by another half-inch marble, over 500 feet away; Mars, by a tiny ball about three tenths of an inch in diameter, more than 800 feet away; Jupiter, by a ball half a foot in diameter, over half a mile away; Saturn, by a five-inch ball, nearly a mile away; Uranus, by a ball two and one fifth inches in diameter, nearly 2 miles away; Neptune, by a ball of two and two fifths inches, nearly 3 miles away; and Pluto, by a marble about three eighths of an inch in diameter, 4 miles away from the five-foot sun.

***Mercury.** Mercury is not only the planet nearest to the sun but it is also the smallest and the swiftest-moving. It is only

about three thousand miles in diameter and is about thirty-six million miles from the sun. Its orbit is less like a perfect circle than that of any of the other planets. It is difficult to see, because one has to look in the direction of the sun to see it.

Lowell Observatory

FIG. 191. In the top left-hand picture Venus is on the opposite side of the sun from the earth. In the bottom left-hand picture Venus is on the same side of the sun as the earth. Can you diagram the positions of the earth, Venus, and the sun when Venus looks largest and when it looks smallest?

*This planet revolves round the sun in eighty-eight days. It is practically certain, moreover, that it always keeps the same side toward the sun. If this is true, the side which is always in the sunlight is hot enough to melt lead, and the dark side is always very cold. Mercury has no atmosphere and no moons, probably because, being so small, it has not sufficient gravitational attraction either to hold an atmosphere or to retain a satellite.

***Venus.** Venus is often called the earth's twin, because it is almost as large as the earth and because the conditions existing on it are more like those on the earth than on any other planet. It has an atmosphere probably about as dense as ours but more cloudy.

*Venus requires two hundred twenty-eight days to travel entirely round its orbit. This planet probably takes several weeks, perhaps even months, to rotate on its axis. One side is therefore very hot and the other side very cold. There would not be so much difference between the temperatures of the two sides as on Mercury, because Venus is farther from the sun and because of its atmosphere.

U. S. National Park Service

FIG. 192. To those of us who are familiar with mountains, the earth's surface seems very uneven and rugged, just as tiny pebbles and mounds on the ground may seem enormous to small insects. Yet if the earth were reduced to the size of an orange, its surface would be smoother than the orange skin. Explain. (Mount Rainier, Washington)

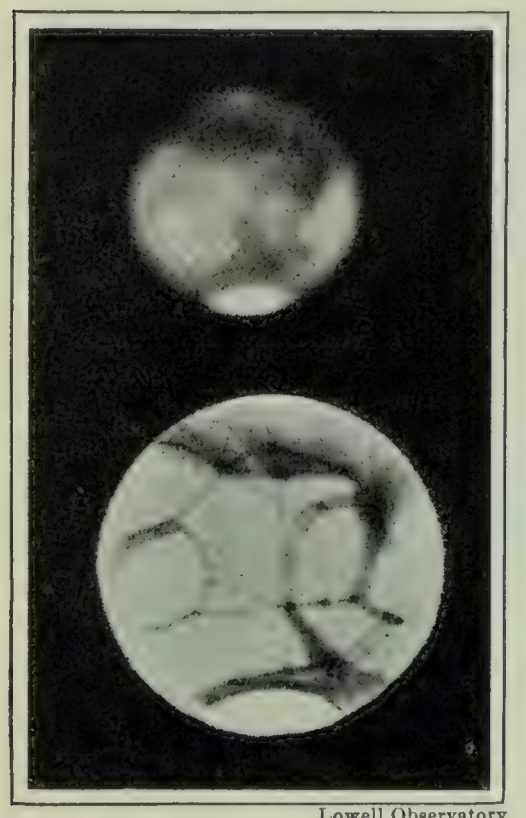
Next to the sun and the moon, Venus at its brightest is the brightest object in the heavens (Fig. 191). For several months it appears in the west as the evening star, then it is not seen again for a few weeks, after which it appears in the east as the morning star.

*__The earth.__ The earth is the largest of the four terrestrial planets. Yet, if it could be viewed from the sun, it would look like a mere speck (Fig. 192). It is about eight thousand miles in diameter and twenty-five thousand miles round at the equator. The atmosphere surrounding the earth is as much a part of it as are the oceans and the land. The interior of the earth is very hot. Yet it is not soft like pitch, but rigid[1] like steel.

*The earth rotates on its axis once in twenty-four hours and makes a complete revolution through its orbit round the sun in

[1] *Rigid* (rij'id): not easily changed in form.

three hundred sixty-five and a quarter days. Its axis is not perpendicular to the plane of its orbit round the sun, but tilts at an angle of $23\frac{1}{2}$ degrees from this perpendicular. Our seasons are due to this tilt of the earth's axis, as will be explained in Chapter XVIII.



Lowell Observatory

FIG. 193. A photograph of Mars (top) and a drawing (bottom) as one observer saw it through a telescope. Note the *canali* in both pictures. State as many reasons as you can why it would be possible for *some sort* of creatures to live on Mars. State as many reasons as you can why it would be impossible for people *like ourselves* to live on Mars

*Mars. Mars is the terrestrial planet farthest from the sun. With the exception of Mercury, Mars is the smallest of the planets. It is about four thousand miles in diameter. It rotates on its axis in twenty-four hours thirty-seven minutes, and makes one revolution round its orbit in six hundred eighty-seven days. Unlike our earth's surface, the surface of Mars is believed to be chiefly land and relatively flat. If it has oceans, they are probably small and shallow. The planet has a reddish[1] color, which is thought to be due to iron compounds in the rocks. With a telescope one can see here and there green patches which may be marshes or vegetation. White spots appear at the poles (Fig. 193), increasing in winter and decreasing in summer. These are thought to be polar ice caps similar to those on the earth.

*Mars has two tiny moons less than ten miles in diameter. It is believed that Mars has an atmosphere. If it has, this atmosphere is not so dense as is that of the earth. Because this blanket of air is so thin, the temperature of Mars changes very

[1] *Ish* on the end of a word means "somewhat," or "tending toward." Thus, *reddish* means "tending toward red"; *sweetish* means "somewhat sweet."

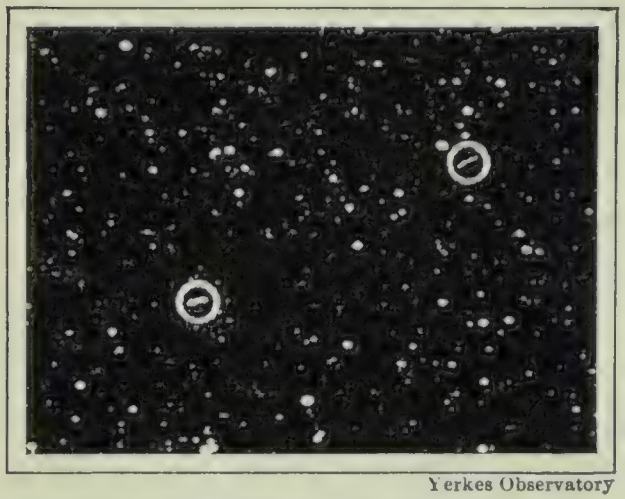
rapidly. Temperature differences between day and night, therefore, are much greater than on the earth. Thus, the noon temperature at a point near the equator of Mars is about 25° C., while the lowest temperature at night at the same spot is about — 75° C., a difference of about 100° C. The climate of Mars is much cooler than that on the earth, because Mars receives less than half as much light and heat from the sun. Why?

*Are there people on Mars? In 1887, when it was the custom to call some broad spots on Mars "seas," an Italian astronomer announced that he had discovered faint lines connecting the "seas." He called these *canali*, meaning "channels." But when his report was translated into English the word was unfortunately translated as "canals." Many astronomers have since observed these lines, but doubt that they are artificial. It is thought by some that these *canali* mark the courses of great irrigation ditches which intelligent beings have built to convey water from the melting snows at the poles. Others think that the larger ones are natural reservoirs or marshes which are fed by storm winds from the poles. It is possible, of course, that there may be creatures living on Mars and that they may have intelligence like that of people on the earth. No scientist, however, would state that such creatures exist or, if they do exist, that they are *people* or are *like us*. In fact, the astronomers have as yet secured no evidence which indicates whether there is or is not life on Mars.

The asteroids, or planetoids. Before the year 1801 astronomers had searched in vain for some sort of planet-like body in the vast space between the orbits of Mars and Jupiter. On January 1, 1801, an Italian astronomer, Piazzi, discovered in this region of the heavens a little globe only about four hundred miles in diameter which he named Ceres.[1] Since then other smaller bodies have been discovered there, one by one, until now more than a thousand of these asteroids are known (Fig. 194). Most of them are very small, perhaps not more than twenty-five miles in diameter. It is probable that there are many others too small to be seen with the telescope. Each has its own orbit round the sun just as the

[1] *Ceres* (see'reez): the largest asteroid; named after the Roman goddess of the harvest.

planets have, and makes a revolution in from three to seven years. The orbits vary from almost perfect circles to ellipses much longer than they are wide.



Yerkes Observatory

FIG. 194. This photograph, taken through a telescope, reveals two asteroids (inside the circles). When an astronomer sees on a plate a long image like these among many round ones (stars), he knows the image is some body in the solar system. Explain

Although all the nine planets revolve round the sun in nearly the same plane, the orbits of some of the asteroids tip at a sharp angle to this plane. Most of the asteroids, those which have the most nearly circular orbits, are between Mars and Jupiter, but those with the elliptical orbits do not remain in this space. Tiny Eros and two other asteroids which are even smaller than Eros, for example, pass closer to the earth than any other known celestial bodies except the moon. None of the asteroids has an atmosphere. They are thought to have very rugged surfaces and may be considered to be merely huge rocks.

Pluto. In 1863 the French astronomer Flammarion predicted that sooner or later someone would discover another planet beyond Neptune. He made this prediction because he had found that Uranus was moving in a way that indicated the influence of another planet. In 1905 the American astronomer Lowell again found and reported evidence of this new planet. On March 13, 1930, Dr. Slipher of the Lowell Observatory at Flagstaff, Arizona, reported that the exact evidence of this expected planet had been found on a photograph made by a young astronomer named Tombaugh.

Pluto is the planet farthest distant from the sun. The facts now available about Pluto show that it is about four billion miles distant from the sun. This distance is more than forty times as far as from the sun to the earth. The year of Pluto

is said to be about two hundred fifty times as long as is the year of the earth. The diameter of this new planet is not over fifty-five hundred miles, which is seven tenths the diameter of the earth.

Self-test on Problem XVI–B. (*Do not write in the book.*) **1.** *Many* other stars besides our sun are known to be surrounded by a group of planets.

2. Mars and Venus shine with a *steadier light* than Alpha Centauri or the polestar.

3. If you were to see in the heavens a body which changed its position with respect to other heavenly bodies from night to night, you would know this body was a *star*.

4. The earth is one of the *larger* planets.

5. The smallest and swiftest-moving planet, and the one nearest the sun, is __(?)__.

6. The planet on which conditions are most like those on the earth is __(?)__.

7. The asteroids are *more* like the planets or the moons than they are like other bodies.

Problem XVI–C · What are the Characteristics of the Great Planets?

Jupiter. Jupiter is by far the largest of the planets of our solar system. If all the other planets and their satellites could be rolled into a ball, this ball would still be smaller than Jupiter. The volume of this planet is more than a thousand times that of the earth. Jupiter rotates on its axis in about ten hours. It revolves round the sun in about twelve years. It has a very cloudy atmosphere. It is probable that these clouds are not composed of condensed water vapor, as are those of the earth's atmosphere, but instead are made up of minute crystals of frozen ammonia. Some of the huge belts of clouds above its equator are as large as our whole earth.

Jupiter has a family of nine satellites, or moons. Four are visible with a small telescope. Ganymede (Fig. 195), the largest, is about halfway between Mercury and Mars in size. The moon nearest Jupiter requires about eighteen hours to revolve in its

orbit around Jupiter. The one farthest away takes nearly seventy days. Two of Jupiter's satellites revolve from east to west. The rest revolve in the usual west-to-east direction.

Mt. Wilson Observatory

FIG. 195. Jupiter and Ganymede (gan'e meed). The white spot to the left of Jupiter is Ganymede. The black spot on Jupiter is Ganymede's shadow. Compare Jupiter and its moons with our solar system. (See "To the Student," p. xvi)

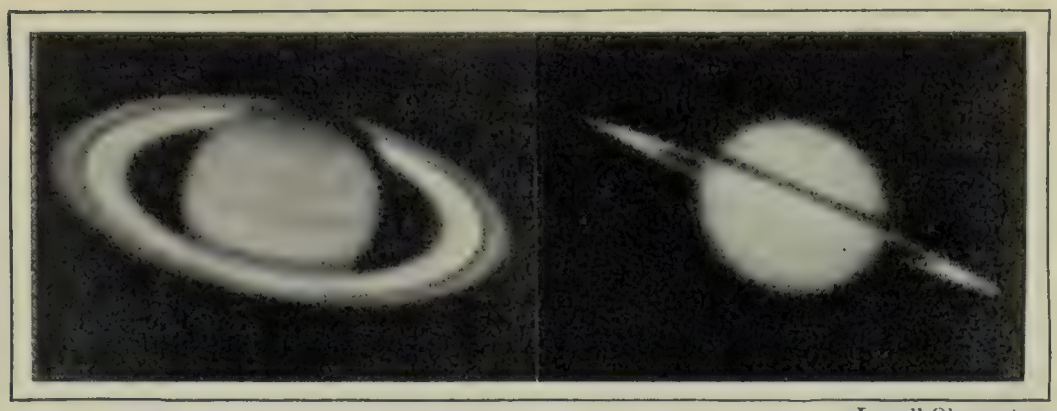
When Jupiter is seen without a telescope, it shines with a steady white light. It is more brilliant than any of the stars except the sun, but is not so bright as Venus at its brightest.

***Saturn.** Saturn is somewhat smaller than Jupiter, but it is like Jupiter in having belts and a cloudy atmosphere. Like Jupiter, it rotates on its axis in about ten hours.

*When viewed without a telescope Saturn is not especially interesting. It glows with a dull yellowish light and is only as bright as a star of the first magnitude.[1] But seen through a telescope it is remarkable. It is surrounded by three rings (Fig. 196). We can easily see a bright outer ring, with a space between it and another broader, still brighter ring. If we should use a telescope that is powerful enough, we could see a third, dim ring inside the second one. These rings are composed of swarms of tiny satellites, probably not bigger than meteors, which revolve round Saturn like any other satellites. These rings seem to be about fifty miles thick and are thousands of miles across. The outer ring has a diameter of about one hundred seventy thousand miles.

Saturn has nine moons besides the tiny ones which compose

[1] The fourteen brightest suns are the stars of the first magnitude. They are not necessarily the biggest stars and they are not the ones nearest the earth.



Lowell Observatory

FIG. 196. Two views of Saturn taken about six years apart. You can see all three rings in the left-hand picture. The inner ring can only be seen against the ball of Saturn. Compare Saturn with Jupiter

the rings. One of these, Titan, is at least as large as Mercury. All these satellites revolve round Saturn in the usual direction, from west to east, except Phoebe. This, the most distant of Saturn's moons, revolves from east to west.

Uranus. Uranus was discovered in 1781 by an English astronomer, William Herschel,[1] with the aid of a telescope which he made himself. This planet is probably similar to Jupiter and Saturn, but it is so far away that accurate observations of its features are difficult. It is known to have four moons. These revolve round it in orbits almost perpendicular to the plane of its own orbit.

Neptune. The story of the discovery of Neptune is one of the most interesting in the whole history of science. After Uranus was discovered the astronomers observed it to compute its orbit. To their surprise they did not find Uranus exactly where they had computed that it should be. Evidently it must be responding to the gravitational attraction of some other body besides the sun. No heavenly body was then known which could be producing this effect upon Uranus. A young Englishman named Adams and a young Frenchman named Leverrier independently began the attempt to solve the problem of Uranus's variation[2] from its computed path. In 1846 first Adams and then Leverrier arrived at practically the same conclusion, though neither knew of the other's work. They concluded that there must be another planet

[1] Herschel was a German by birth and during his early life was a musician by profession. Later he lived in England, where he did his astronomical work.

[2] *Variation* (va ri a'shun): the act of varying or differing.

farther out from the sun which must be in a certain position in the sky to attract Uranus. When a search of that portion of the sky was later made with telescopes, Neptune was found in almost the exact place where Adams and Leverrier had predicted it would be.

*Neptune is Uranus's twin and is more like Uranus than Venus is like the earth. It is about thirty-five thousand miles in diameter. It requires nearly one hundred sixty-five years to revolve in its orbit round the sun, and it probably rotates in less than twenty hours. Little is yet known about its surface features, because it is too far away for even the great telescopes to reveal its surface clearly.

Self-test on Problem XVI–C. (*Do not write in the book.*) 1. Of the four great planets the planet which is largest and which is also nearest to the earth and to the sun is __(?)__.

2. The great planets have *fewer* moons than have the smaller ones.

3. The planet which is surrounded by three rings composed of tiny satellites is *Neptune*.

4. There are *no* planets which have moons as large as Mercury or larger.

5. The presence of *Saturn* was known before it was ever seen.

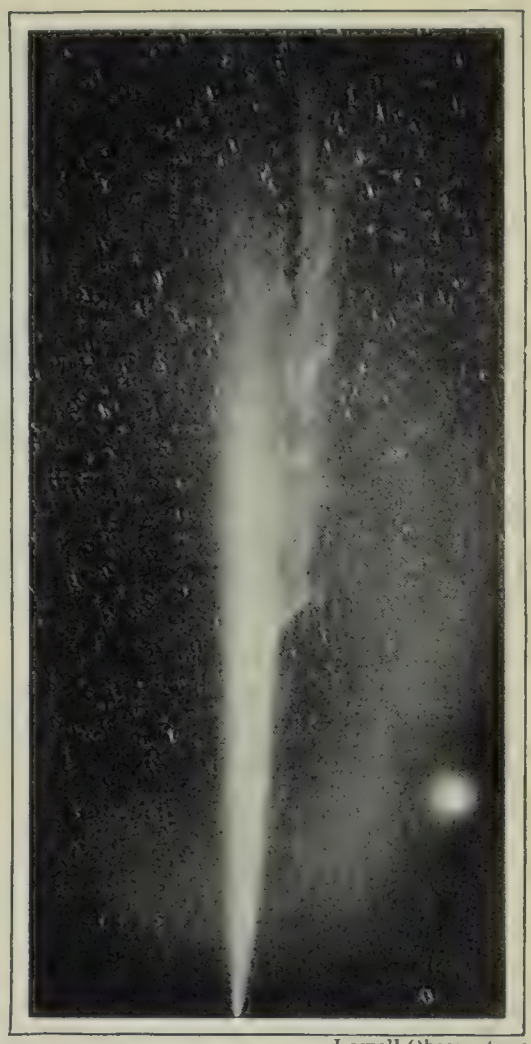
6. We should expect the planet Neptune to have a *denser* atmosphere than Pluto or Mars, because its gravitational attraction is *smaller*.

Problem XVI–D · What are the Characteristics of Comets and Meteors?

***Comets.** Sometimes astronomers in searching the heavens with their telescopes may note a dim little patch of light which they have not previously noted. Night after night they watch it. When they observe that it moves through the constellations, like the planets, they know that it is a comet. As it approaches near the sun it greatly increases its speed. As it approaches the sun, moreover, the comet develops a tail which streams across the heavens for millions of miles (Fig. 197).

Up to the present time perhaps a thousand comets have been registered, but only a few of these have been visible without the

telescope. Whenever they have been visible without a telescope, however, they have been regarded with awe and superstition. Even in 1910, when Halley's comet returned (as it does every seventy-six years), there were ignorant and superstitious people who believed the comet to be a bad omen, and who predicted dire calamities, even the end of the world. But there is nothing unnatural about comets. They are controlled by the same natural laws as are the other members of the solar system and obey these laws in exactly the same way.



Lowell Observatory

FIG. 197. Halley's comet, photographed May 13, 1910. The bright spot to the right is Venus. The trail of a meteor (or "shooting star") crosses the comet's tail. The telescope was kept pointed at the comet; hence the stars and the meteor made streaks on the photograph. Explain

*Meteors. If we watch the sky on a clear moonless night, especially in April, August, or November, we may see the streaks of light which are called shooting stars (Fig. 197). They are not stars, but meteors — small bits of matter which are pulled to our earth by gravitational attraction. Falling at the rate of from seven or eight to forty-five miles a second, they become incandescent chiefly by striking the air, just as a lead bullet sometimes becomes hot enough to melt when it is fired against a rock. They also gain heat by friction in passing through the air. The great heat vaporizes the outside of the meteor (all of a small one); it condenses as dust. Probably more than ten million of these meteors, weighing on an average less than an ounce each, burn up in the earth's atmosphere every day, leaving dust which slowly settles.

What is the relation between comets and meteors? Like comets, meteors were long regarded with superstition. Even today certain Mohammedans believe that the showers of meteors, or meteoric swarms, are fire which good angels throw at bad angels to drive them from the sky. Astronomers now generally believe that the meteoric swarms are parts of comets and their tails which have been broken up and scattered as innumerable small fragments along the orbits of those comets. In fact, the breaking up of Biela's comet was observed by astronomers. This comet completed the circle of its orbit in a little more than six and a half years, and had been observed early in the last century. When it appeared in 1846 its head was seen to be in two parts. In a later trip the two portions were seen to be far apart. The comet was never seen again. But in 1872, when the earth crossed the trail of the vanished comet, there was a wonderful shower of meteors for several hours. Some of these meteors were "fire balls" that looked to be as big as the moon.

A. M. N. H.

FIG. 198. The Cape York meteorite, one of the largest and heaviest known. Special Report: The Canyon Diablo; the North Carolina shower of meteorites. (Consult an encyclopedia or a recent textbook of astronomy)

Meteorites. Occasionally stones fall through our atmosphere to the ground. These are called meteorites. They are believed to be of the same general nature as the smallest asteroids. They usually weigh from a few pounds to several tons (Fig. 198). There are many of these meteorites on exhibition in various parts of the world, and others are constantly being found. One of the largest known meteorites is the "Cape York." This, with other meteorites, is exhibited in the American Museum of Natural History in New York City. It weighs about thirty-seven tons. No less

than a hundred meteorites fall to the earth each year. Most of them are irregular lumps of stone, but a few are almost pure iron.

Self-test on Problem XVI–D. (*Do not write in the book.*) **1.** A body which is seen in a slightly different place with respect to the other heavenly bodies from night to night, and which has a tail, is (1) a meteorite; (2) a meteor; (3) comet; (4) an asteroid; (5) a satellite of a planet.

2. The comets which return from time to time are satellites of the *planets.*

3. Meteors are *larger* than the sun.

4. Meteors are (1) stars; (2) suns; (3) comets; (4) small bodies of stone or iron; (5) satellites of the sun.

5. If it were not for the earth's atmosphere it is probable that *fewer* meteorites would strike the earth each year than now do.

Self-test on Scientific Principles. How would you explain and illustrate this principle: "All bodies in the solar system are controlled by the gravitational attraction of the sun"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Give reasons why, since Mercury rotates once in eighty-eight days, its side next to the sun is very hot.

2. How does the atmosphere of the earth and of Venus help to keep the temperature on each of these planets more even?

3. Storms more violent than any we know of on the earth are probably passing constantly between the hot and the cold sides of Venus. Remembering the cause of land and sea breezes, can you explain (1) whether these gales would blow from the warm to the cold side, or the opposite? (2) why these gales should be so violent?

4. Venus approaches closer to the earth than almost any other heavenly body except the moon, but we cannot study Venus when it is nearest, because we cannot see it. If, however, there are intelligent beings on Venus, they have their best view of the earth at this time. Can you explain these statements?

5. Draw a diagram showing the position of the earth, Mercury, and the sun when Mercury is nearest the earth.

6. Can you think of a possible reason why none of the asteroids has an atmosphere?

7. If the sun were viewed from Pluto, it would look like a fairly bright star. Explain.

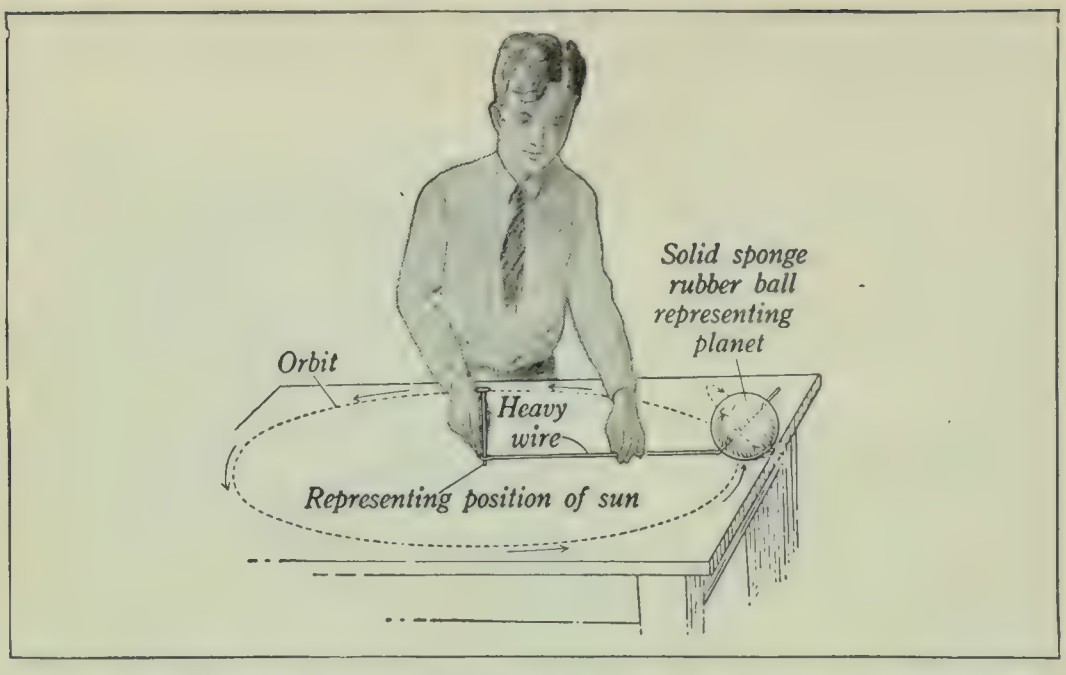


FIG. 199. This diagram gives the general idea of the rotation and revolution of a planet. However, it represents two conditions which are not true of the earth. What are these conditions? Can you plan a change in this apparatus which will make one or both of these conditions true for the earth?

Group Report. The data for the earth are included in the table. Can you find the data by means of which to complete the table? (*Do not write in the book.*)

FACTS ABOUT THE PLANETS

Planet	Diameter in Miles	Distance from the Sun	Time of Rotation	Time of Revolution	Number of Satellites
Mercury					
Venus . .					
Earth . .	8000	93,000,000	24 hours	$365\frac{1}{4}$ days	1
Mars . .					
Asteroids					
Jupiter .					
Saturn .					
Uranus .					
Neptune					
Pluto . .					

Projects. 1. To make a model illustrating the rotation of a planet on its axis and the revolution of the planet in its orbit round the sun. Bend a heavy wire as in Fig. 199. Use a rubber ball or tennis ball to represent

the planet. Hold the free end of the wire firmly while you move the "planet" end round it in a circle to represent the orbit. Keep the "planet" against the table top so that it will rotate as it revolves round the "sun."

2. To make a diagram showing the relative sizes of the sun and the nine planets of the solar system. Draw on a large sheet of cardboard a circle at least a foot in diameter to represent the sun. Then at various points inside this circle draw circles of the proper sizes to represent the various planets as compared with the sun. The table on page 274 will furnish the needed data, or facts, regarding the sizes of the planets. Draw also a circle near Jupiter to represent Ganymede and another near Saturn to represent Titan. These circles will, of course, be less accurate in relative size than the others because the exact diameters of these moons of the great planets are not given in the text. Label each of the twelve circles with its name and its diameter.

3. To make a diagram showing the relative sizes of the orbits of the planets. On a large sheet of cardboard or of stiff wrapping paper make a diagram similar to Fig. 190, p. 274, showing the orbits of all the planets drawn in their correct relative sizes, but instead of using the distances in miles as on Fig. 190 use as the units the number of years required for the revolution of each planet as given in the table on page 274. Thus the circle representing the earth would be one unit in diameter; that of Mercury would be .24 unit in diameter. Label each circle with the name of the planet it represents.

Exercise on Scientific Method. What phases of the scientific method (p. 9) are illustrated by the account of the discovery of Neptune?

Exercise on Scientific Attitudes. What scientific attitudes (pp. 12 and 13) did the people referred to on page 285 lack?

Special Reports. 1. What is the story of Halley's comet? of some of the other celebrated comets?

2. H. G. Wells has written an interesting story, *The War of the Worlds*, which tells of the attempted conquest of the earth by "people" from Mars, and another, *In the Days of the Comet*, which tells of the effects on the earth and its people when a comet approached and struck the earth. Neither book is intended to be scientific, yet each is partly founded on science. How much of each book is scientific?

Books for Reference

Lewis, Isabel M. Astronomy for Young People. Dodd, Mead and Company, New York.

Mather, K. F. Old Mother Earth. Harvard University Press, Cambridge.

Chapter XVII · Earth's Nearest Neighbor, the Moon

Questions this Chapter Answers

What are the surface features of the moon?
What are the climatic conditions of the moon?
What are the gravitational conditions of the moon?
How are the phases of the moon caused?
What conditions cause eclipses of the sun and the moon?
What causes the tides?
Of what importance are the tides?

Problem XVII-A · What are the Characteristics of the Moon?

***The moon.** The movements and varying appearance of the moon have interested people as long as records tell about people's interests. The moon is about two thousand miles in diameter. It has a volume about one sixtieth and a weight about one eightieth that of the earth. It is about two hundred forty thousand miles, or nearly a quarter of a million miles, from the earth. The moon seems large to us because it is so close as compared with other astronomical bodies. From century to century the lunar (moon's) surface remains unchanged except for such slight changes as may be caused by falling meteors and meteorites.

Lunar craters. When we look at the moon, even without a telescope, its surface appears to be very rugged and uneven (Fig. 200). With a good telescope we can see clearly what its surface is like. Unlike the surface of the earth, great areas of the moon's surface are dotted with thousands of round depressions, or pits, which look like the craters[1] of enormous inactive volcanoes (Fig. 4, *A*, p. 7). The floors of some are above, and of others below, and of still others at the same level with, the surrounding surface of the moon. Their rims, however, are always higher than the surrounding lunar surface. Some of these depres-

[1] *Crater* (kra'ter): the chimney-like opening in a volcano.

Yerkes Observatory

FIG. 200. The full moon as it looks through a telescope. **Special Report:** To what extent is H. G. Wells's story *The First Men in the Moon* scientific, and to what extent is it unscientific?

sions are many times larger than any volcanic craters on the earth. These depressions are usually called lunar craters or moon craters. It is not known, however, that they were formed by volcanoes. The largest of these craters has been named Copernicus,[1] after the great Polish astronomer. It is fifty-six miles wide and about two and a half miles deep. The depth of the deepest moon crater is about four and a half miles. Most of the craters are less than three miles in depth. Often craters will be found inside larger ones, or perhaps a single mountain will tower a mile or more into the air from the floor of one large crater.

*__Lunar mountains.__ Besides these crater-like depressions, the moon has mountain chains much like the mountain chains on the earth, with towering peaks, some of them nearly five miles high (Fig. 201). Not all the moon's surface is rugged. Parts of it are great smooth areas, with only here and there a crater or a single slender peak. These conspicuous smooth areas of the moon's surface are wrongly called seas.

[1] *Copernicus* (ko per'ni kus): the founder of modern astronomy (1473–1543).

Lunar streaks and clefts. From some of the largest lunar craters light-colored streaks extend in many directions for great distances. One is nearly two thousand miles long. Thus in Fig. 200 some of these streaks may be seen extending across the lunar landscape from some of the craters near the middle and at the top of the picture. Apparently these streaks are neither higher nor lower than the surrounding surface, but run in straight lines across the pitted lunar landscape. No scientist has yet been able to explain satisfactorily what the streaks are or what caused them, though some think that they were caused by the staining of the lunar surface by gases escaping from inside the moon. In addition to these streaks, the lunar surface has numerous huge cracks called clefts or rills. Although these are sometimes more than a hundred miles long, they are usually narrow, perhaps not more than half a mile or so wide.

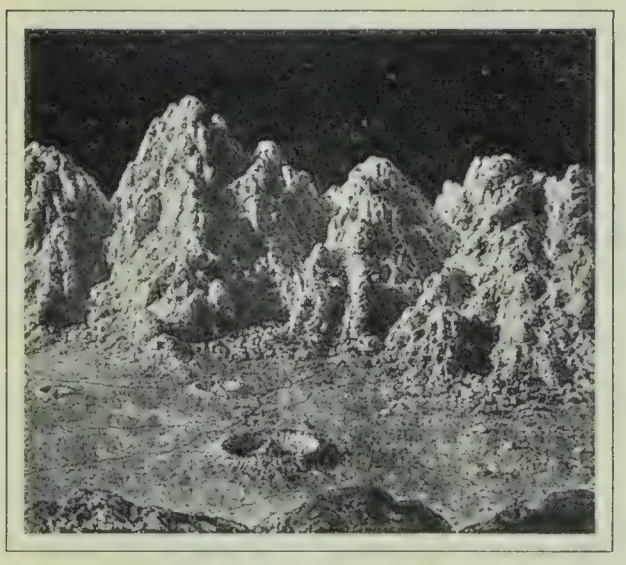


FIG. 201. How a lunar mountain might look if seen from the moon's surface. How do you account for the differences between this mountain and Mt. Rainier (p. 277)? [1]

What part of the moon do we see? The moon always keeps the same side toward the earth. The lunar orbit is not in the same plane as the earth's orbit. The moon therefore swings above and below the earth, giving us a glimpse of more than half its surface. It is probable that we shall never see the rest of its surface, but there is no reason to believe that this is very different from the part that we do see.

Conditions on the moon. The moon has no atmosphere, no water, and no life of any sort. In the sunshine on the lunar surface the temperature becomes higher than the boiling point of water (212° F.), but a short distance away in the black shadow it is far

[1] From Nasmyth and Carpenter's *The Moon*, by permission of John Murray, publisher.

below the freezing point of water. In some recent experiments with the 100-inch telescope on Mt. Wilson it was found that the temperature on the moon may vary about 400° F. between midday and shortly after sunset. These great differences of temperature are due to the fact that there is no atmosphere to hold and distribute the heat. For the same reason the temperature during the lunar night, which is two weeks long, may fall almost to absolute zero, which is the coldest temperature possible anywhere.

Gravitation on the moon. If it were possible for one of us to be on the moon, he would be able to travel about very swiftly, because the gravitational attraction at the surface of the moon is only about one sixth that on the earth. This statement means that a man weighing one hundred eighty pounds on the earth would weigh only about thirty pounds on the moon. Therefore if he could jump five feet on the earth, he could just as easily jump about thirty feet on the moon.

The sky as it would appear from the moon. If one could look from the moon, he would see the stars shining brilliantly in a black sky. These stars would be visible during both the lunar day and the lunar night. He would see the earth, bright in its reflected sunlight, looking like a huge, almost motionless disk in the sky, about four times as wide as the moon looks to us. He would be able to see its oceans and continents spin by (Fig. 202) as it rotates daily, and would even be able to observe its clouds and storms.

***Lunar day and night.** The moon revolves round the earth in twenty-seven and one-third days. Since the moon always keeps the same side toward the earth, the sun shines on every part of its surface during the moon's complete revolution round the earth. Daylight on any part of the moon, therefore, would last about fourteen of our days, and darkness the same length of time.

Self-test on Problem XVII–A. (*Do not write in the book.*) **1.** The moon is about _ _(?)_ _ miles from the earth.

2. *All* parts of the moon are rugged and mountainous.

3. Clefts or rills on the moon are (1) light-colored streaks; (2) craters of extinct volcanoes; (3) long, narrow cracks; (4) high mountains; (5) mountain chains.

4. Name the conditions on the moon which would make life impossible for ourselves.

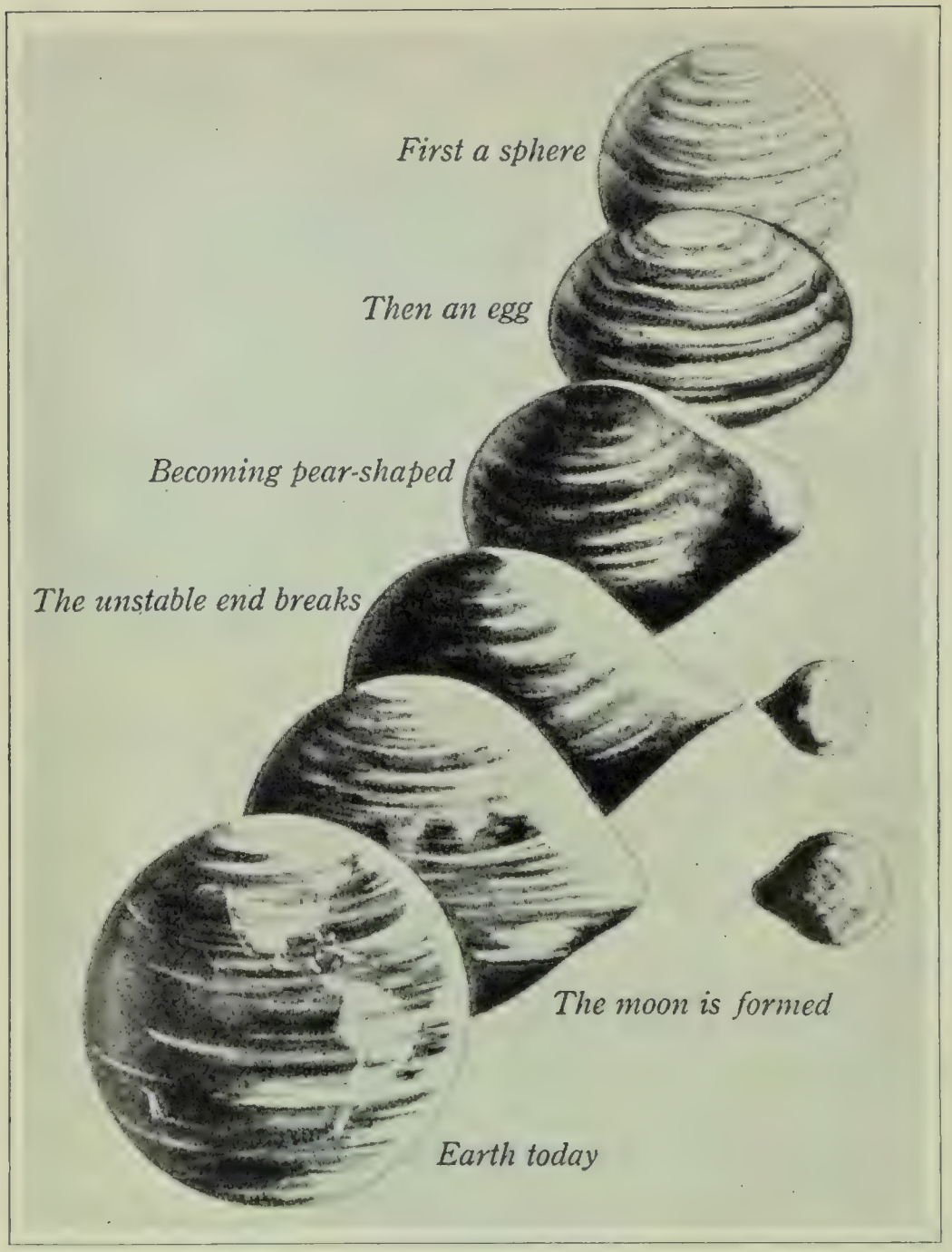


FIG. 202. One hypothesis that was made to explain how the moon might have been formed. Another hypothesis is given on page 320. In the hypothesis pictured here, what would cause the moon to break away from the whirling earth?[1]

[1] From H. T. Stetson's *Man and the Stars*, by permission of McGraw-Hill Book Company, Inc.

5. The same spot on the moon would remain in the sunlight for about _ _(?)_ _ days.

6. A pound of any substance on the moon would occupy *less* space than a pound of the same substance on the earth.

Problem XVII-B · What are Some Important Phenomena Connected with the Moon's Movements?

***Phases of the moon.** The moon is not incandescent like the sun. It shines, like the planets and the asteroids, by reflected sunlight. We know from watching it that it sometimes looks like a thin crescent and sometimes like a round golden disk, as Venus looks in Fig. 191, p. 276. The differences in the appearance of the moon during the month are called the phases of the moon. When the moon is at the point in its revolution where it is between the earth and the sun, the illuminated[1] side is away from the earth. Next we can see a tiny bright crescent in the western sky with its points toward the left. As the moon revolves we are able to see a little more of the lighted half each night. This means that the phases of the moon change slowly from one to another. After seven days we are able to see half the lighted half, or one quarter of the moon's surface. We call this the first quarter. Slowly, as the moon revolves in its orbit, we are able to see more and more of the lighted half until, seven nights after the first quarter, we can see the entire lighted half. We call this full moon. After full moon the moon begins to wane; that is, we are able to see less of the lighted half each night. Seven nights after full moon, we can again see only half the lighted half. We call this the third quarter. During the next seven days the crescent which we can see becomes smaller and smaller, with its points toward our right, until it disappears at new moon. The phases are then repeated.

Experiment 44. How can you represent the phases of the moon? Take a basketball to represent the moon and a floor lamp across the room to represent the sun Let your head represent the earth. Hold the basketball a little higher than your head in the line between you and the lamp (Fig. 203). This position represents new moon. Slowly turn

[1] *Illuminate* (il lu'min ate) or *illumine* (il lu'min): to make light.

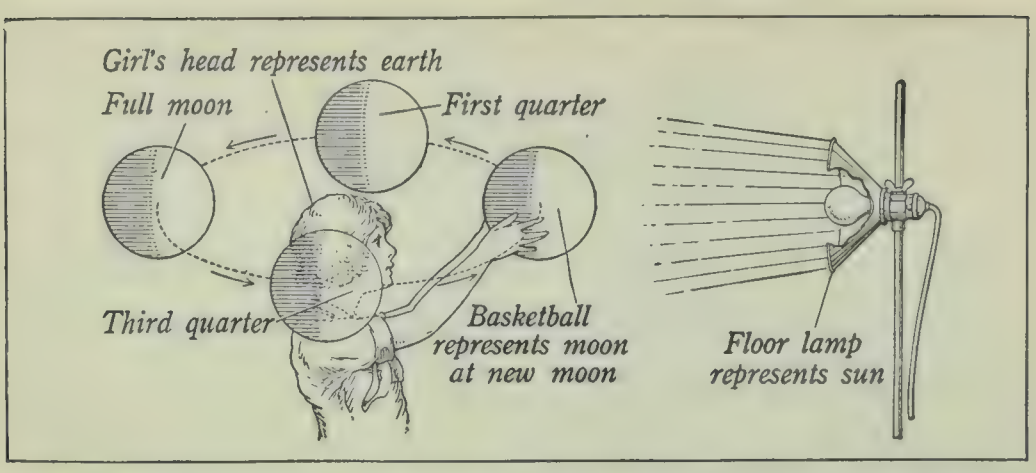


FIG. 203. What picture of Venus (Fig. 191, p. 276) corresponds to each phase of the moon? Why does the disk of Venus appear to change so greatly in size from phase to phase while the disk of the moon does not?

toward your left and note how the crescent of the lighted side increases. Revolve the ball one fourth of the way round your head (the earth) to the position indicated as first quarter. How much of the lighted half can you see now? How much of the lighted half can you see when you are halfway around? three fourths of the way around? all the way around?

Eclipses. From earliest times solar eclipses have been regarded with superstition, as they are even yet by some ignorant people. Certain of the Hindus believe that an eclipse of the sun occurs when the dragon Rahu swallows the sun. The cause of eclipses, however, was at least partly understood many centuries ago. More than two thousand years before Christ two official Chinese astronomers, Hsi and Ho, were executed because they failed to predict the solar eclipse and to perform the usual rites during it.

***Solar eclipses.** Both the earth and the moon cast cone-shaped shadows, because the sun is so much larger than they are. Sometimes at new moon the moon is exactly between the sun and the earth and near enough so that the tip of its cone-shaped shadow passes across the surface of the earth (Fig. 205, *A*). If we happen to be inside the tip of the shadow we cannot see any of the sun, because the moon shuts off our view. We call this a total eclipse of the sun (Fig. 204, and Fig. 205, *A*). If we are not in the shadow, but still in the partial shadow, we can see only part of the sun. This is called a partial eclipse of the sun.

When the Sun Disappears behind the Moon

TO OBSERVE a total eclipse of the sun is a rare and wonderful event, experienced by few people, because the path of complete shadow is only a few miles wide. Through heavily smoked glass we watch the sun from the time the disk of the moon first is visible as a dot on the sun's rim. Slowly the moon's disk passes across the face of the sun, but the sunlight does not begin to get dim until most of the sun is covered. The sunlight through the branches of trees throws crescent-shaped spots of sunlight on the ground—not round

Van Vleck Observatory

FIG. 204. A total eclipse of the sun. Nobody ever saw a solar eclipse during the night or a lunar eclipse during the day. Explain

spots such as we usually see. Shortly before the sun disappears behind the advancing moon, a white sheet placed on the ground shows wavering bands of light and shadow. Lovely soap-bubble colors are seen in the sky near the sun. Finally we notice that the light is beginning to grow dim. Birds and chickens seek their perches, as if evening were approaching. We see the moon's shadow racing toward us at enormous speed along the ground from the west. It reaches us at the same instant that we see the sun's disk entirely covered. The light is now a strange pale twilight. This lasts from less than one minute to occasionally more than seven minutes. During this time one can see perhaps a flaming red prominence somewhere round the edge of the sun's disk, while all round the sun is the beautiful pearly light, called the corona, from the sun's atmosphere. Stars twinkle brightly in the darkened sky. Slowly the moon passes entirely across the face of the sun and the normal daylight returns, with nothing left to indicate that an eclipse has occurred.

Sometimes when the moon is between the sun and the earth the moon is too far away for its shadow to reach the earth. This

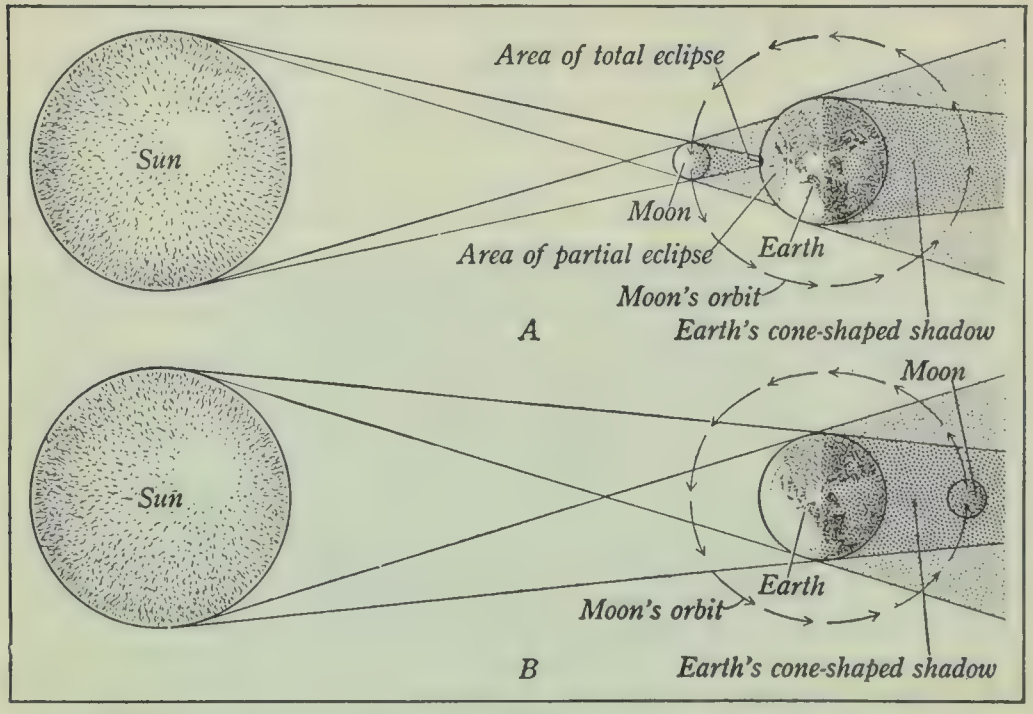


FIG. 205. Diagrams showing eclipses of the sun (*A*) and the moon (*B*). Solar eclipses can occur only at new moon and lunar eclipses only at full moon. Why?

is because the earth is not quite in the center of the moon's orbit. Consequently we are not conscious that an eclipse is taking place, because the sunlight is not dimmed; but with a smoked glass we should be able to see the bright ring of the sun surrounding the dark disk of the moon.

***Lunar eclipses.** Whenever the moon passes into the shadow of the earth we have a total lunar eclipse (Fig. 205, *B*). Since the moon has no light of its own, it becomes almost invisible when the earth shuts off from it the direct rays of the sun.

Self-test on Problem XVII–B. (*Do not write in the book.*) **1.** If the moon did not revolve around the earth, it would have *fewer* phases.

2. Eclipses of the *sun* occur only at full moon, when the *sun* is between the moon and the *earth*.

3. Eclipses of the *moon* occur only at *full* moon, when the moon is between the earth and the sun.

4. There would be *fewer* eclipses of the moon if the moon did not revolve around the earth.

5. During a solar eclipse there is *total* darkness.

6. If the moon's orbit were parallel with the earth's orbit, there would be an eclipse of the sun and an eclipse of the moon about once a *month.*

Problem XVII-C · How does the Energy of the Tides Result from the Moon and the Sun?

*__The tides.__ Those who live near the ocean know that the water's edge keeps changing its place. They know that the water line moves gradually farther toward the land for about six hours, then slowly moves farther out for the next six hours. This movement of the water is called the tide. In some places the water line may be more than a quarter of a mile farther in at high tide than at low tide.

*__What causes the tides?__ There are several hypotheses to explain the tides. Probably the most generally accepted one is based on the gravitational attraction of the moon and the sun on the earth. When the moon and the sun are on the same side of the earth, as at new moon (Fig. 206, *A*), they are both exerting their gravitational attractions in the same direction. All portions of the earth are then attracted in the direction of the sun and the moon. But not all portions are attracted equally. The nearer a portion is to the attracting bodies, the more strongly it is attracted. Thus x is more strongly attracted than y and z (Fig. 206, *A*) because it is closer to the moon and the sun. For the same reason u and w are more strongly attracted than v. The result of these unequal attractions is a strain which tends to make the earth somewhat like a football in shape. The solid earth is too rigid to move, but the water is not. Hence the water is forced into slight bulges[1] on opposite sides of the earth but in a line with the moon and the sun. These bulges are the tides. Similar conditions result at full moon, when the sun, the earth, and the moon are again in a line.

*As the earth rotates these bulges follow the moon. The result is that places on the ocean shore have a high tide every time one

[1] *Bulge* (bulj) : to swell out ; a swelling, a swollen part of the surface.

of these two bulges reaches it, and a low tide in between two high tides. Because the moon revolves in its orbit while the earth is

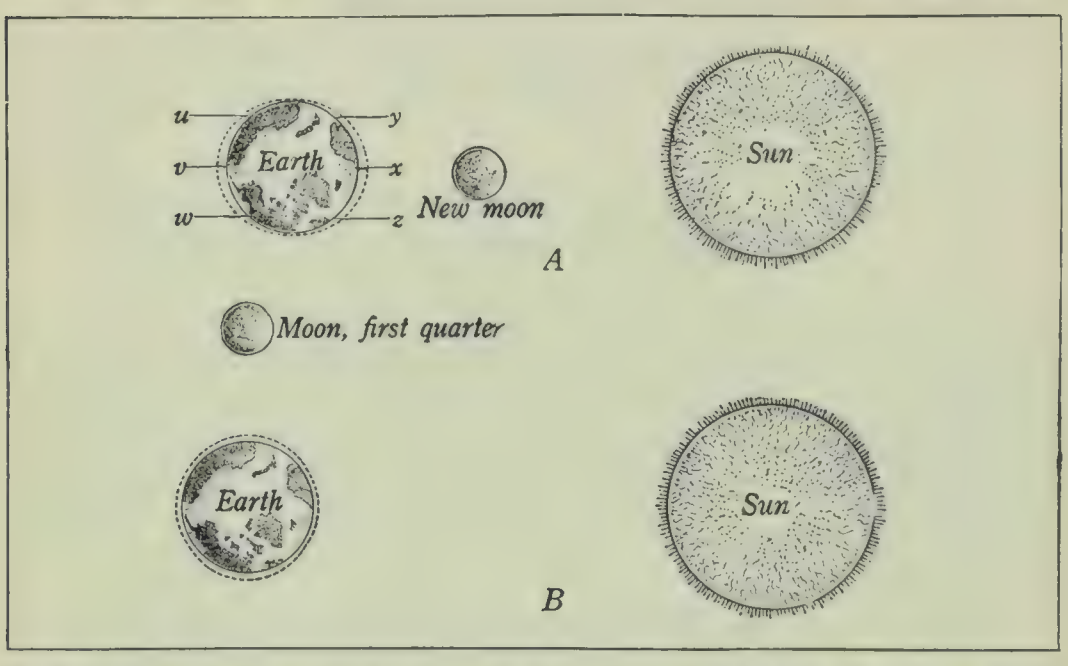


FIG. 206. Diagrams showing the cause of spring tides (*A*) and of neap tides (*B*). If the moon were nearer the earth, would the tides be greater or smaller than they now are? Explain

rotating, these tidal waves do not travel round the earth in exactly twenty-four hours, but take twenty-four hours and fifty-two minutes. Hence each place on the ocean shore has one high tide and one low tide every twelve hours and twenty-six minutes.

*Spring tides and neap tides. At new moon and full moon the gravitational attractions of the sun and the moon are in the same straight line, hence the high tides are highest and the low tides are lowest at this time. These new-moon and full-moon tides are called spring tides (Fig. 206, *A*), though the name has nothing whatever to do with the seasons. At first and third quarters, when the sun and the moon are exerting their gravitational attractions at right angles on the oceans, the high tides and low tides are smaller than at any other times during the month. These small tides are called neap tides (Fig. 206, *B*).

*Importance of tides. The tides are of great importance to ocean travel, since large vessels can enter and leave many of the ports only at high tides. The tides sometimes affect ocean travel

by digging new channels in bays and river mouths and by filling others with sand and sediment. This makes constant dredging[1] necessary to keep the channels clear. The tides are also important to various fishing industries, particularly the gathering of oysters, clams, and other shellfish along the shores. They also keep the beaches clear of garbage[2] and wastes by washing the shores twice a day. In some places in western Europe the energy of the tides is used to turn small mills for grinding grain. At the mouth of the river Seine a few large power plants change the tidal[3] energy into electrical energy. Engineers have been unable to plan a way to make use of the three-to-six-foot differences which exist in most places between high and low tides. These tides seem to be a possible future source of useful energy (Fig. 207).

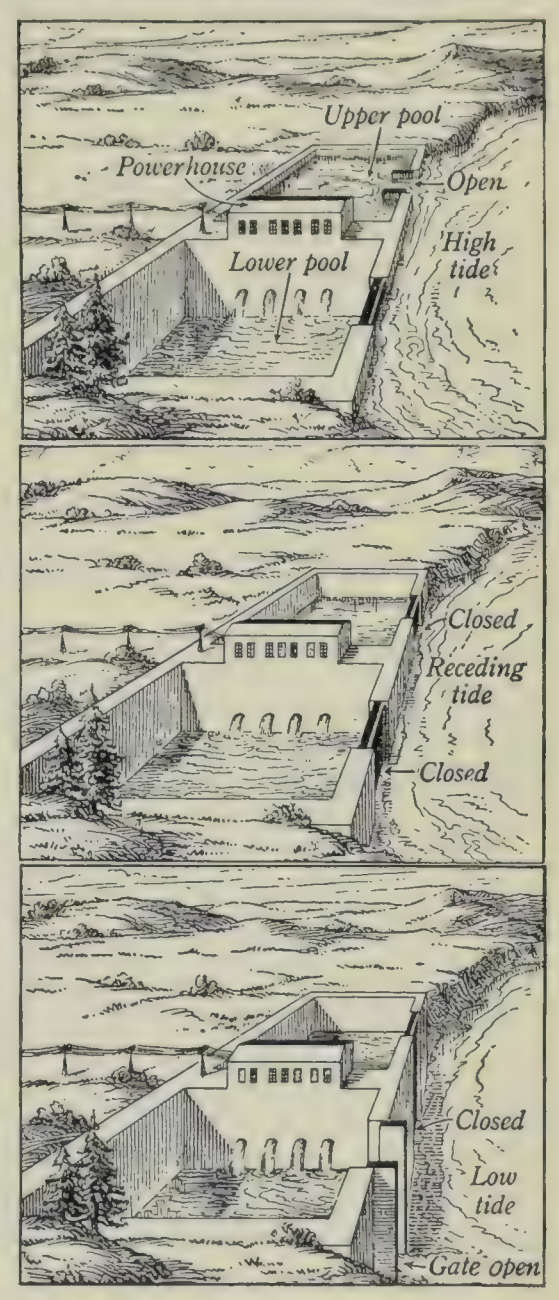


FIG. 207. A proposed plan to use tidal energy off the coast of Maine to develop 500,000 H. P. Can you explain these drawings?[4]

Tidal waves and earthquake waves. The tidal waves must not be confused with the great and often destructive waves which sometimes accompany earthquakes and volcanic explosions. They must also not be confused with the ordinary waves which are always found

[1] *Dredge* (drej): to remove deposits of mud and other materials from a channel.

[2] *Garbage* (gar'baj): waste materials from the kitchen and table.

[3] *Tidal* (ti'dl): having to do with the tides.

[4] From Millikan, Gale, and Pyle's *Elements of Physics*.

in the oceans and great lakes and which are chiefly due to friction caused by the wind sweeping over the surface of the water. Tidal waves are merely the succession of high and low tides and hence reach every point on the ocean shore twice in a little more than a day.

Self-test on Problem XVII–C. (*Do not write in the book.*) 1. Tides are influenced more by the *sun* than by the *moon.*

2. If the sun were nearer the earth, the tides would be *smaller.*

3. Spring and neap tides occur only at certain *seasons* of the *year.*

4. The ocean shore is bare for a longer distance at *low* than at *high* tide.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Would one gather shellfish at spring or neap tides, and at high or low tides?

2. Why is the term *lunar seas* an incorrect term?

3. Solar eclipses are actually more frequent than lunar eclipses, yet more people have observed lunar eclipses than have observed solar eclipses. Explain.

4. How is it possible to see the moon during a lunar eclipse?

5. Sometimes one can see the moon during the morning or the afternoon. How is this possible?

6. Can you draw a diagram showing how it has been possible to see more than half the surface of the moon?

7. If the earth, the moon, and the planets all revolved in exactly the same plane around the sun, would it ever be possible for the moon to come between the earth and another planet? Would it ever be possible for another of the planets to come between the earth and the moon? Support your answers by means of diagrams.

Special Report. Jules Verne wrote an interesting adventure story, *A Trip to the Moon.* It was not intended to be scientific; yet it was founded partly on scientific facts. What parts of it are scientific?

Books for Reference

Chambers, G. F. The Story of Eclipses. D. Appleton-Century Company, Inc., New York.

Service, Garrett P. The Story of the Moon. D. Appleton-Century Company, Inc., New York.

Chapter XVIII · Keeping Track of Time and Place

Questions this Chapter Answers

What causes the seasons?
Why is summer warmer than winter?
What are sun time, standard time, and daylight-saving time?
How is time of day determined?
What purpose is served by calendars?
How are places located on the earth?

Problem XVIII–A · What Causes the Seasons?

Early ideas regarding the seasons. Primitive peoples did not know enough astronomy to enable them to invent an accurate calendar. No doubt they noted the regular return of full moon, as well as the succession of the seasons. Thus, the Indians would locate some event by saying that it had occurred "three moons" before, or they would give the age of a child as "two summers."

Before men became civilized, however, they doubtless noted that the length of daylight changed from the time of one full moon to the next. They came to know that daylight lasted longer than the darkness during the warmer period, or summer; and that the darkness lasted longer than the daylight during the colder period, or winter. They were unable, of course, to account for these phenomena, and consequently invented strange and interesting myths to explain the "longer" and "shorter" days (see page 307).

Why are there seasons? *Experiment 45.* What causes the seasons; that is, why are there more hours of daylight than of darkness during the summer and more hours of darkness than of daylight during the winter? Also, why is it warmer during the summer than during the winter? Set up the apparatus as in Fig. 208, with the end of the flashlight in the cardboard mailing tube so that no light from the flashlight is visible except from the end of the mailing tube. Place the globe about an inch from the end of the tube and in the position

marked "March 21" in Fig. 209. Darken the room. Note that the axis of the globe points neither toward nor away from the light but

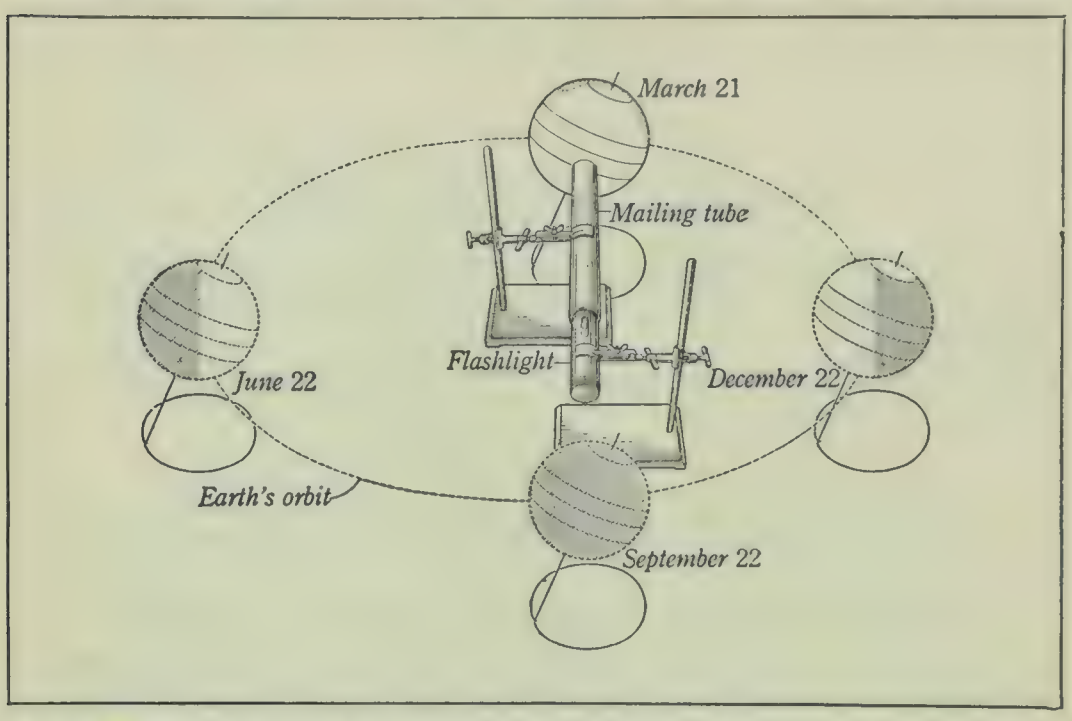


FIG. 208. Would there be any seasons if the earth did not rotate on its axis? Justify your answer

at right angles to it, and that the middle of the spot of light from the tube falls on the equator. This position represents March 21. Note that on March 21 the direct rays of the sun fall upon the equator. Rotate (spin) the globe to represent day and night. Does the sunlight on March 21 extend beyond the north pole or the south pole or exactly to each pole? Note, while the globe rotates, that every spot on the earth is in the light during exactly one half a complete rotation. How many hours of daylight and darkness, therefore, are there on every part of the earth on March 21?

Without changing the direction in which the axis of the globe tilts, move the globe one quarter of the way around the orbit to the position marked, in Fig. 209, June 22. Rotate the flashlight and tube also so that the end from which the light comes is again about an inch from the globe. On what circle does the middle of the spot of light representing the direct rays of the sun now strike? Rotate the globe to represent day and night on this date. Does the same circle which the direct rays of the sun strike remain in the direct rays of the sun during the complete rotation, or twenty-four hours, on June 22? Is the light brighter or less bright in the United States and Canada than in

South America on June 22? Is the north pole or the south pole in the daylight on June 22? Which pole is in the darkness on June 22? Is

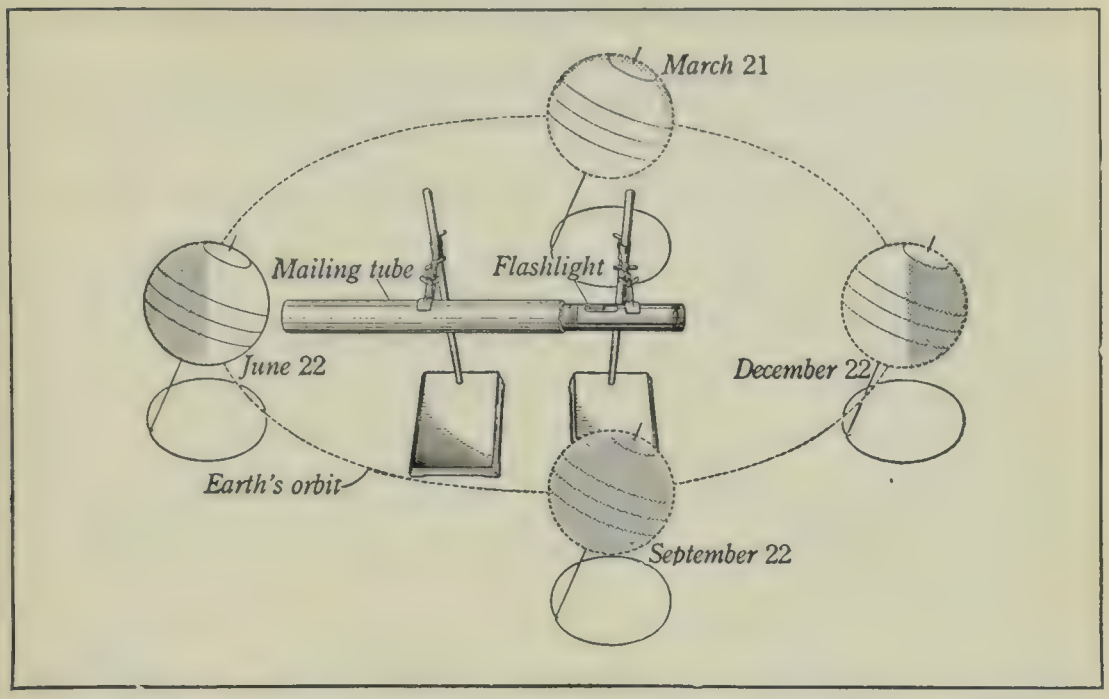


FIG. 209. Would there be seasons if the earth's axis were tilted at an angle of 90° from the perpendicular, that is, if its axis were parallel with its orbit? Justify your answer

the Northern Hemisphere having summer or winter on June 22? Is the Southern Hemisphere having summer or winter on June 22?

Without changing the direction in which the axis of the globe tilts, again move the globe one quarter farther around in its orbit, to September 22. Adjust the light as before. Rotate the globe to represent day and night. Does the same circle on the earth which the direct rays of the sun strike remain in the direct rays of the sun during a complete rotation, or twenty-four hours, on September 22? What is the name of this circle? How many hours of daylight are there at every point on the earth on September 22? How many hours of darkness?

Without changing the direction in which the axis of the globe tilts, again move the globe one quarter of the way around the circle to the position marked in the figure as December 22. Adjust the light as before. On what circle of the earth do the direct rays of the sun, as represented by the middle of the spot of light, strike on December 22? Rotate the globe to represent day and night. Does the same circle on the earth which the direct rays of the sun strike remain in the direct sunlight during a complete rotation, or twenty-four hours, on December 22? Which pole is in the sunlight during the entire twenty-four hours on

December 22? Is the light brighter or less bright in the United States than in Brazil on December 22? Which pole is in darkness on that date? Which circle, the arctic or the antarctic, is entirely in the sunlight on December 22? Which circle is entirely in the darkness on December 22? Is the Southern Hemisphere having summer or winter on December 22? Is the Northern Hemisphere having summer or winter on December 22?

Select one or more endings in each of the following sentences which make the statement true:

There are seasons on the earth — that is, at every place on the earth there are more hours of daylight than of darkness at certain times and more hours of darkness than of daylight at others — because: (1) the earth's axis tilts; (2) the earth rotates on its axis; (3) the earth is slightly farther from the sun on December 22 than on June 22; (4) the weather changes frequently; (5) the moon has changing phases; (6) the earth revolves around the sun; (7) the earth is slightly flat at the poles; (8) the climate is affected by the seasons; (9) the earth has an atmosphere.

It is warmer during the summer than during the winter because (1) the earth is nearer the sun; (2) the weather is better; (3) the sun's light and heat strike more directly; (4) the earth rotates on its axis; (5) the summer months are always warmer than the winter months; (6) the winter months are always colder than the summer months; (7) there are more hours of daylight during which that part of the earth may absorb heat; (8) the earth revolves around the sun in three hundred sixty-five and a quarter days; (9) the atmosphere is sometimes cloudy and sometimes clear.

***Seasons and the earth's axis.** If the earth's axis were vertical to the plane of its orbit (that is, if the earth's axis did not tilt), there would be no longest and no shortest day in the year. There would be no seasons, because the vertical rays of the sun would always strike the equator. Hence every spot on the earth would then have twelve hours of daylight and twelve hours of darkness *every* day in the year.

*Since the earth's axis tilts away from the perpendicular to the plane of its orbit, there are only two days in the year, March 21 and September 22, when its axis is not tilted either toward the sun or away from it (Fig. 210, *a* and *c*). On these two days the vertical rays of the sun fall on the equator, with the result that every spot on the earth has twelve hours of daylight and twelve hours of darkness. Day and night on these two dates are equal. For

How One Indian Tribe Tried to Account for the Seasons

OJEEG was a little Indian boy who longed to be a great hunter like his father. But at that time all the days were short, and there was always ice and snow. Ojeeg could not stay out hunting long because of the severe cold. So he asked his father to use magic and make summer for him.

Big Hunter loved his little son and longed to please him. He secured the aid of his friends, Otter, Beaver, and Badger. They all decided they must

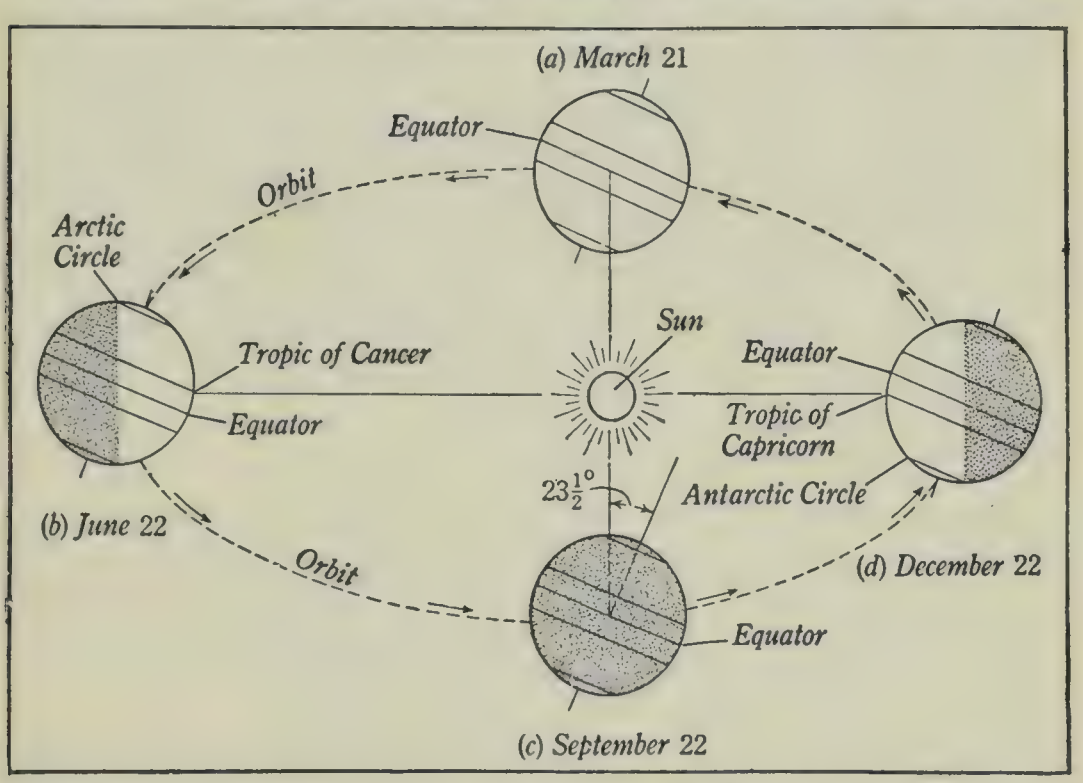


FIG. 210. Diagram showing the cause of the seasons. Would there be any seasons if the earth did not revolve around the sun? Explain

make a hole in the sky. After traveling to the top of a high mountain, Otter made a great jump, but he could not reach the sky. Next Beaver tried, but he also failed. Then Big Hunter tried another plan. First he climbed on the strong shoulders of mighty Badger and then leaped with all his strength. He touched the sky! A second and a third time he jumped, and finally the sky opened, allowing sweet summer to rush through. Little Ojeeg hunted and fished as much as he pleased, and since then the long warm days of summer come every year.

this reason March 21 is called the spring equinox[1] or vernal equinox, and September 22 the fall equinox or autumnal equinox.

*As the earth travels round its orbit after March 21 the upper end of its axis points more directly toward the sun from day to day. The vertical rays of the sun therefore strike farther and farther north of the equator. On June 22 the earth has reached the point in its orbit where its axis points most directly toward the sun (Fig. 210, *b*). Since the axis tilts at an angle of $23\frac{1}{2}$ degrees, the vertical rays of the sun now strike $23\frac{1}{2}$ degrees above the equator. The sunlight reaches $23\frac{1}{2}$ degrees beyond the north pole, throwing all the arctic circle into the sunlight while all the antarctic circle is in darkness (Fig. 210). This date is called the summer solstice.[2] The imaginary[3] circle round the earth $23\frac{1}{2}$ degrees north of the equator, where the vertical rays of the sun fall on June 22, is called the tropic of Cancer. On June 22 every spot on the earth north of the equator has more than twelve hours of daylight (Fig. 210, *b*). We are now having the beginning of summer. On June 22 every place south of the equator is having less than twelve hours of sunlight.

*As the earth continues round its orbit its axis gradually points less directly toward the sun. Day by day the vertical rays of the sun move south from the tropic of Cancer. On September 22, when the earth's axis is pointing neither toward nor away from the sun, the direct rays of the sun rest again on the equator (Fig. 210, *c*). This date is called the fall equinox.

*The earth travels on. The northern end of its axis now tilts slightly away from the sun. The vertical rays of the sun leave the equator and continue to travel gradually farther south. On December 22 they have reached their most southern point. This date is called the winter solstice. On this date the northern end of the earth's axis tilts away from the sun. The sun's direct rays now strike the earth $23\frac{1}{2}$ degrees south of the equator. The imaginary circle drawn on the rotating earth by the vertical rays of the sun on December 22 is called the tropic of Capricorn. All

[1] *Equinox* (e'kwi noks): the dates March 21 and September 22, when the days and the nights are equal.

[2] *Solstice* (sol'stis): the dates June 22 and December 22, when the direct rays of the sun strike farthest north and farthest south of the equator.

[3] *Imaginary* (i maj'i na ry): existing only in the mind.

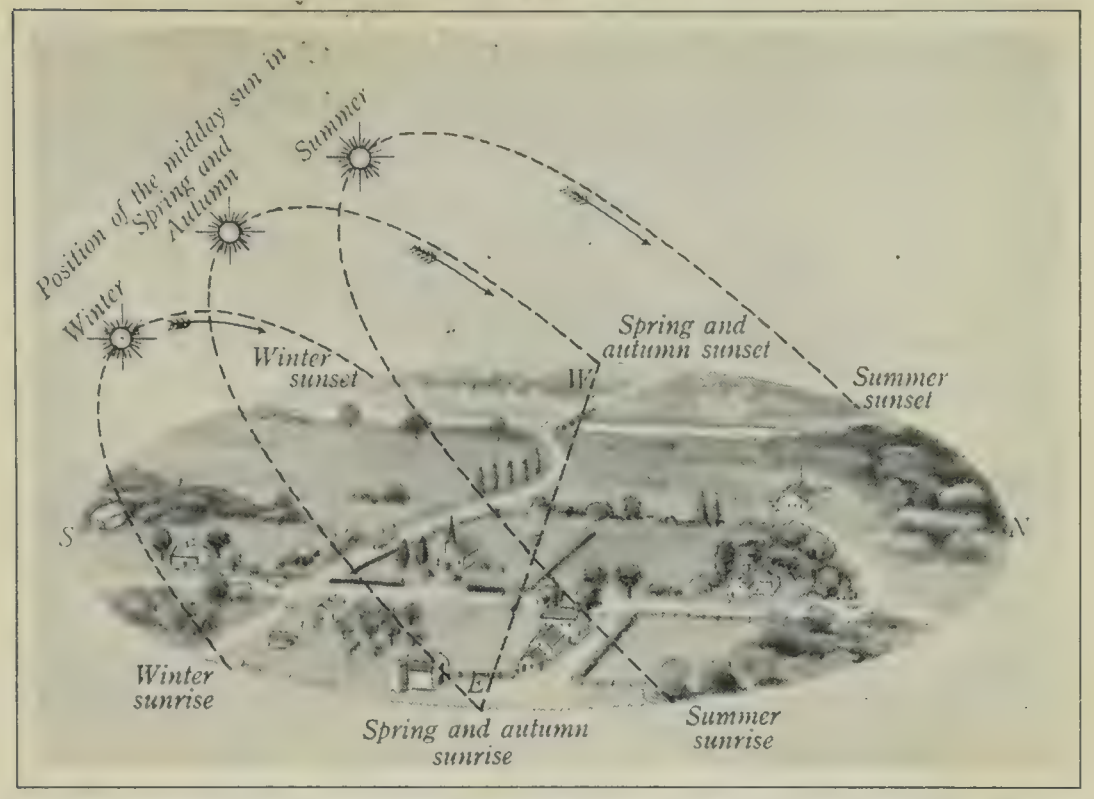


FIG. 211. Sunrise and sunset at different seasons at 40° north latitude. In what directions would you face the rising sun in spring? summer? autumn? winter?

the antarctic circle is now in sunlight and all the arctic circle is in darkness. Every spot on the earth south of the equator on December 22 has more than twelve hours of daylight and fewer than twelve hours of darkness. In Argentina and South Africa, therefore, people have summer when we are having winter. Thus their seasons are always the reverse of ours.

*As the earth continues in its orbit the direct rays of the sun gradually travel north toward the equator and the tropic of Cancer, and the seasons are repeated.

*The imaginary circles which represent on the earth the sun's rays during the year mark the boundaries of the zones. Thus, the vertical rays of the sun pass back and forth across the torrid zone, between the tropics of Cancer and Capricorn. The arctic and antarctic circles include all the places on the earth which at some time in the year can have more than twenty-four hours of continuous daylight or darkness. Places in the temperate zones never have the direct rays of the sun and never have twenty-four hours of daylight or darkness at a time.

Why is summer warmer than winter? The earth's orbit is not *quite* a perfect circle but is slightly elliptical. The sun, moreover, is not exactly in the center of it. Fig. 210, p. 307, shows this last fact, but shows the sun to be much farther away from the center of the earth's orbit than is actually the case. But Fig. 210 shows us also a surprising fact. The earth is nearest the sun during our winter. We who live in the northern hemisphere are actually *farther* from the sun during our summer than during our winter. How, then, can our summers be warmer than our winters? There are two reasons: (1) we actually receive more light and heat from the sun during the summer, because the sun's rays strike more directly down upon us than in winter; (2) the sun is pouring down upon us its heat and light for so many more hours of every twenty-four during the summer than during the winter (Fig. 211). The result is that in summer the Northern Hemisphere is receiving radiant energy from the sun faster than it radiates the energy away. In the winter the opposite is the case.

Self-test on Problem XVIII–A. (*Do not write in the book.*) **1.** There are *six hours* of continuous daylight and darkness at the north and south poles.

2. The two days during which there are twelve hours of daylight and twelve hours of darkness everywhere on the earth are __(?)__ and __(?)__.

3. On December 22 the vertical rays of the sun strike the earth at the __(?)__.

4. The vertical rays of the sun never strike the earth farther north than the __(?)__ or farther south than the __(?)__.

5. If you lived south of the equator you would be nearer the sun during the *winter* than during the *summer*.

Problem XVIII–B · How are Time and Location Determined?

Counting the hours. If the earth always kept the same side toward the sun, like Mercury, the time of day at any spot on the earth would never change. Any spot on the earth would always be having either unchanging daylight or unchanging darkness, year after year and century after century. But the earth does rotate, and this rotation causes sunrise, noon, sunset, and night.

*For convenience both in locating places on the earth and in reckoning time the equator is divided into exactly three hundred

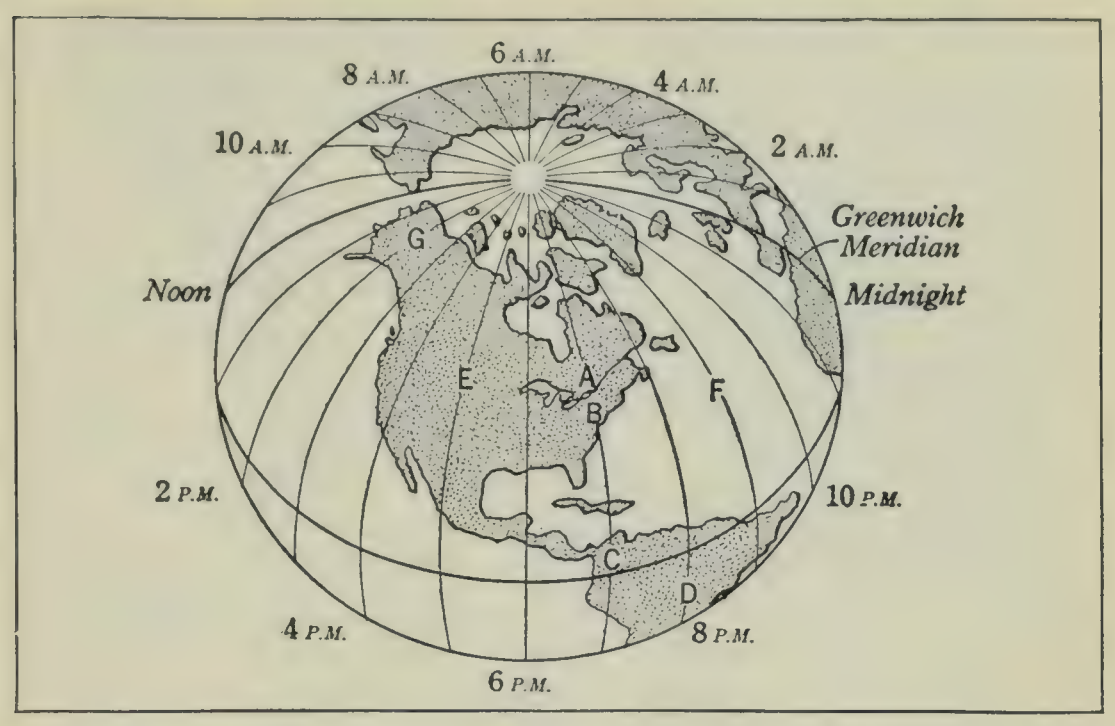


FIG. 212. Meridians of longitude. When it is 5 A.M. at city A, it is also 5 A.M. at cities B and C, it is 6 A.M. at city D, and 3 A.M. at city E. Explain. If it is exactly 10 P.M. at city E, what time is it at F and at G?

sixty parts called degrees. Each degree is further divided into sixty minutes, and each minute into sixty seconds. These minutes and seconds are parts of a circle, not minutes and seconds of time. Imaginary lines are drawn on the earth which run north and south through the degrees, minutes, and seconds and end at the poles (Fig. 212). These imaginary lines are called meridians of longitude.

*Since there are exactly twenty-four hours in a day, the earth rotates one twenty-fourth of 360 degrees, or 15 degrees, in one hour. Therefore any two meridians 15 degrees apart have a difference in time amounting to exactly one hour, because each meridian has sunrise exactly one hour later than the meridian 15 degrees east of it (Fig. 212). The meridian of longitude which passes through Greenwich is called the zero meridian or prime meridian, and time all over the earth is referred to it.

Sun time. The exact hour of the day at any point on the earth is the sun time. Noon at any place is the exact second in the

day when the sun is nearest overhead. All points which are located on the same meridian are having noon at exactly the same

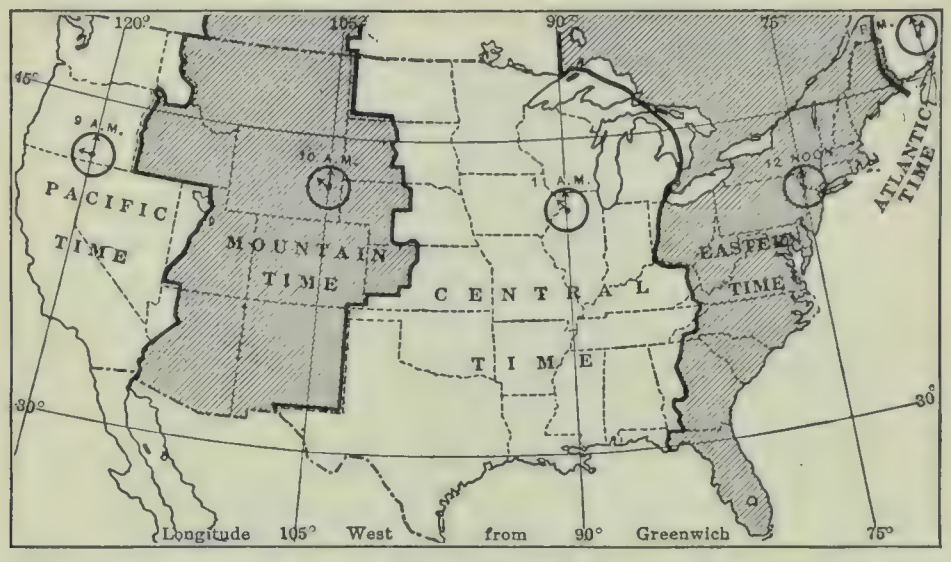


FIG. 213. The standard time zones of the United States.[1] When it is noon, standard time, where you live, what is the standard time at Boston? Los Angeles?

instant. At that instant it is afternoon at all places which are east of that meridian and forenoon at all places west of it.

Thus, because Portland, Oregon, is west of New York, the sun time there is earlier than the sun time in New York. People in Portland, Oregon, may know before 2 P.M. the results of a baseball game which did not begin in the East until 2:30 P.M. of the same date. In New York on New Year's Day people may begin listening at 5 P.M. to the broadcast of the football game which begins in the "Rose Bowl" at Pasadena, California, at 2 P.M.

Standard, or railroad, time. If we tried to keep our watches exactly correct by sun time we should have to be putting them ahead whenever we went a few miles east and back whenever we went west. To avoid confusion and bother of this sort the civilized nations in 1884 established standard time. According to this plan time belts about fifteen degrees wide were established round the earth, with each of the hour circles in the middle of the time belt.

The United States is marked off into four of these belts, each roughly fifteen degrees across. For convenience every place

[1] By state law or local regulation, a place near a boundary sometimes adopts the time of the adjacent zone.

within any time belt has the same standard time (Fig. 213). Thus New York and Pittsburgh have the same standard time, though Pittsburgh's sun time is considerably earlier than New York's. Chicago's standard time is exactly one hour slower, that is, earlier, than are New York's and Pittsburgh's. If you were traveling from Chicago to New York, you would have to put your watch ahead only once, and that would be when you crossed into the Eastern Standard Time belt.

A. M. N. H.

FIG. 214. Calendar Stone or "Stone of the Sun" of the Aztecs. It is a single carved stone which was dug from the site of the ceremonial center of Mexico City in 1790. It represents the sun and the history of the world, its creation and destruction, according to the Aztec myth. **Question for Debate:** *Resolved*, That calendars are more necessary to our modern civilization than clocks

Daylight saving. Many parts of the country have "fast time," that is, time one hour ahead of standard time. This "fast time" is known as "daylight-saving time." More than one hundred fifty years ago Benjamin Franklin suggested the idea of daylight saving. It is only within relatively few years, however, that daylight saving has been established in various parts of this country. The purpose of daylight saving is to start the working day an hour earlier, so that people can be through with the day's work and ready for recreation while there is still considerable daylight left. Thus in summer there is time for baseball, swimming, and other outdoor recreations between dinner and dark, because we have added an extra hour of daylight to our waking day. To accomplish this some places keep the clocks one hour ahead of the standard time all the year round. In others the time is put one hour ahead of standard time in April and is set back again one hour in October. Considerable confusion results from having different times in neighboring cities.

The calendar. Many of the ancient civilized peoples established calendars of their own to keep track of their historic dates. There were the Egyptian calendar, the Hebrew calendar, the Chinese calendar, the Mohammedan calendar, and others (Fig. 214). No two of these began with the same year, because each people began its own calendar with some important date in its own history. These calendars were all more or less inexact, because the astronomers did not have accurate instruments with which to make their astronomical measurements. In the first century before Christ, Julius Caesar established the Julian calendar, making every year three hundred sixty-five and a quarter days long. In the sixteenth century Pope Gregory XIII established the Gregorian calendar. This was more accurate than the Julian calendar. The Gregorian calendar was not adopted in England until nearly two centuries later, however, and it has been adopted in Greece and Russia only within recent years. It is now used in this country and in most of the civilized world, but by no means in all of it.

FIG. 215. Ship A is in distress and sends out an SOS call by radio, giving its position as 45° W. (longitude) and 50° N. (latitude). Ship B catches the signal and sends back a message to A, stating that it is at 40° W. 50° N. and is hastening to the rescue. Does each boat know exactly where the other is? Can ship B go directly to ship A? Ships C and D also catch the distress signal but are too far away to help. Can you give the position of ship C?

Locating places on the earth. If you were stating the location of your home, you would need to give the names of the two nearest cross-streets. Places on the earth are located similarly. The meridians of longitude enable us to know how many degrees east

or west of London any place is. But if we are going to locate a place *exactly*, we must also know how many degrees north or south of the equator it is. For this purpose, with the equator as a starting line, imaginary circles called parallels of latitude are marked off on the earth in the same manner as the meridians of longitude, but running *east* and *west* round the earth. Places north of the equator are said to be in "north latitude"; those south of the equator, in "south latitude" (Fig. 215). Thus the north pole is 90 degrees north latitude, and the south pole 90 degrees south latitude. The longitude of the north and south poles is zero. In Fig. 215 the location of the ship at *D* would be 20° N. (latitude) and 30° W. (longitude).

Self-test on Problem XVIII–B. (*Do not write in the book.*) **1.** Every spot on the earth has exactly the same sun time as every other spot which is *east* or *west* of it.

2. When it is noon at London it is *morning* at Chicago.

3. When it is noon at Chicago it is *afternoon* at San Francisco.

4. There are *three* standard-time belts in the United States.

5. With daylight saving we sleep *more* hours during daylight than without daylight saving.

6. Standard time is *more* accurate for practically all places than sun time.

7. A year is very nearly __(?)__ days.

8. We can locate a place exactly on the earth if we know its __(?)__ and its __(?)__.

9. When it is 9 A.M. at longitude 20° W., it is __(?)__ at 35° W. longitude and __(?)__ at 5° W. longitude.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is it that the people of Vermont associate snow with Christmas and the people of Rio de Janeiro, Brazil, do not?

2. How is it possible for boys in Alaska to play baseball at 11 P.M. on June 22?

3. Norway is called the Land of the Midnight Sun. Explain.

4. How do you account for the fact that there are six months of daylight followed by six months of darkness at the north and south poles?

5. Are the north and south poles having daylight at the same time?

6. Why is it more correct to say that we live *north* of the equator than to say we live above it?

7. The axis of Mars tilts at nearly the same angle as the axis of the earth. Jupiter's axis scarcely tilts at all. Would either Mars or Jupiter have marked seasons? Would both? If either has marked seasons, would they be longer or shorter than the earth's? Why?

8. Why do afternoon newspapers in San Francisco contain more European news than afternoon papers in Boston?

9. When the Gregorian calendar was adopted in England in 1752, the day following September 3 was made September 13. Why was this necessary?

10. Suppose in August you were to drive from Miami, Florida, to Toronto, Ontario. Should you find more or fewer hours of daylight at the latter city than at the former? Explain.

Exercise on Scientific Attitudes. Although the Gregorian calendar was at once recognized to be superior to the Julian calendar, yet it was centuries before it was generally adopted in civilized Europe. What scientific attitudes (pp. 12 and 13) did the people lack who refused to adopt the Gregorian calendar?

Special Reports. 1. What is the international date line? Why was it established? How is it used? (Consult a textbook of geography or an encyclopedia.)

2. Describe one of the calendars mentioned on page 314.

3. What are some recent plans for improving the calendar?

4. How can one find the day of the week for any given date? (Find "perpetual calendar" in an encyclopedia.)

5. What were water clocks? When were they used? How were they made? (Find "clepsydra" in an encyclopedia.)

6. What are sundials? How are they made? Are they suitable for practical use?

7. What is the story of the "Nuremberg Egg"?

8. What is the history of "Big Ben," and what are its interesting features?

Books for Reference

Overton, G. L. Clocks and Watches. Pitman Publishing Corporation, New York.

Parker, Bertha. The Story of our Calendar and Telling Time through the Ages. American Council of Education.

UNIT VII · *The Changing Earth and the Wealth it Contains*

PROBLEMS DISCUSSED IN THIS UNIT

Let us imagine ourselves four hundred million years ago on the spot where Chicago now is. We find ourselves on a great coral reef in a warm inland sea, which, to our astonishment, we learn is a branch of the Arctic Ocean. Millions of years slowly pass. The ocean disappears. At length we find ourselves near the southern end of a sheet of ice which covers nearly all of the northern part of North America. Again ages pass. We find ourselves in a great fresh-water lake. But it is not Lake Michigan; it is much smaller and different in shape. More millions of years pass. We are now on a lake shore, but not even this is Lake Michigan. Though somewhat like it, this lake is immensely larger. Many more centuries slowly go by. We find ourselves at last on the shore of the Lake Michigan of our day.

Changes such as those just described have been taking place ever since the earth was formed. Their records have been left in the rocks.

Let us shift our attention from the changes which have been taking place on the earth's surface to the riches to be found in the earth. From earliest times the earth has been a storehouse from which man has secured the various substances to satisfy his needs. From the resources of the earth he has learned, with the aid of science, to produce all the marvels of the modern world. This unit discusses these topics:

How did the earth come to be as it now is?
What are the processes which are constantly producing changes in the earth's surface?
What sources of energy are provided by the earth's interior?
What are the properties of some valuable minerals and rocks?
How were rocks formed?

Chapter XIX · The Changing Surface of the Earth

Questions this Chapter Answers

How do scientists believe the solar system and the earth were formed?
What are volcanism, gradation, and diastrophism, and why are these processes important?
What are the nature and the various agents of weathering and erosion?
How are weathering and erosion related to soil making?
How is soil formed?
Of what is soil composed?
What are the characteristics of residual and transported soils?
How has man increased erosion?
How is man attempting to reduce erosion?

Problem XIX-A · How did the Earth Come to Be as it Now Is?

How the solar system was formed. Nobody knows for certain how the solar system was formed. The astronomers and other scientists have offered several hypotheses which attempt to explain its formation. The one that is now most widely accepted by scientists is the planetesimal[1] hypothesis. According to the planetesimal hypothesis all the bodies in our solar system — the sun, the planets, the asteroids, the satellites, and the meteors and meteorites — were once part of one star, or sun. As it drifted through space it chanced to pass fairly close to another star (that is, within perhaps a hundred million miles of it), as indeed it would be expected to do once in about every thousand million million years. The gravitational attraction of each star upon the other produced enormous tides. Finally the tidal force and the explosive force from within the sun became so great that the sun expelled some of its matter into the space around it. The result was a nebula, similar to those shown in Fig. 186, p. 268, though much smaller. In the middle was a big knot of matter composed

[1] *Planetesimal* (plan et es'i ml): a small piece of matter in the heavens.

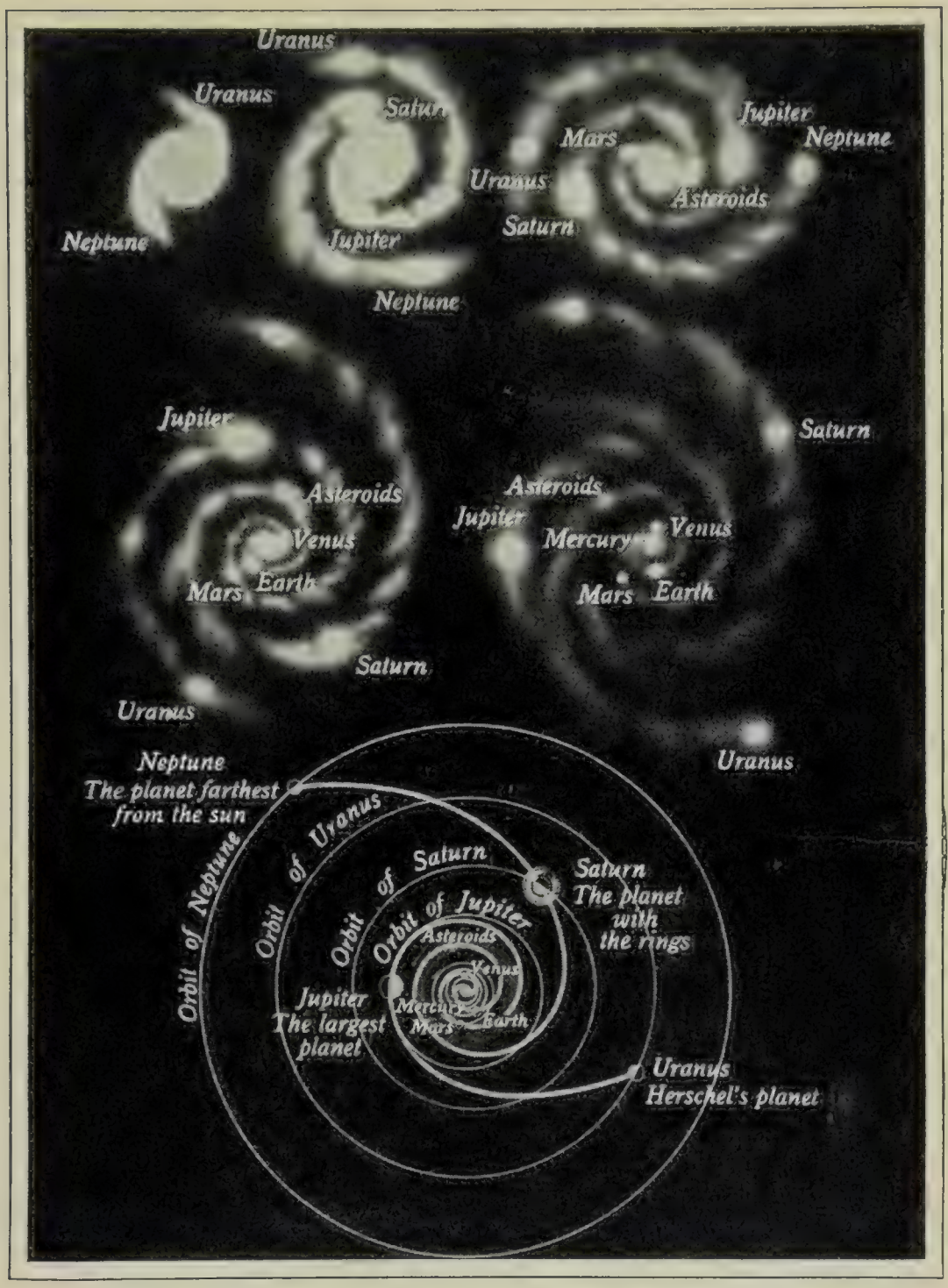


FIG. 216. Diagram illustrating the planetesimal hypothesis.[1] This diagram was made before the discovery of Pluto. According to the planetesimal hypothesis, at what stage of their development would the sun and the planets grow fastest? Explain

[1] From *The Book of Knowledge*, by permission of the publishers.

of most of the original sun. Scattered here and there through the cloud of gases, dust, and planetesimals composing the nebula were other smaller knots of various sizes (Fig. 216).

The gravitational attraction of the passing star as it passed the newly formed nebula started the whole cloud rotating around the central mass. This rotation prevented the gravitational attraction of the central body from pulling back into itself the materials composing the nebula. Consequently these continued to circle round the central knot in elliptical orbits. As they traveled in their orbits during succeeding ages they gathered up by gravitational attraction the smaller bodies and planetesimals which came near them, just as the earth is now constantly gathering up meteors and meteorites. The larger knots after ages of time grew into planets, and smaller bodies which were close enough to them to obey their gravitational attractions circled round them as moons. Other small knots, not near enough to the planet knots to become moons, grew into independent small bodies circling round the central sun knot as asteroids and planetesimals.

How the earth was formed. Scientists know that the earth is very old. Its age is probably not less than several hundred million years and may be more than a billion years. Scientists also know that the earth is constantly changing in various ways. They know that these changes follow each other in an orderly way, as the results of natural causes or laws. They do not yet know the exact nature of all these laws. They are constantly making new hypotheses, or are changing the older ones when the discovery of new facts makes it certain that the older hypotheses are not sound. Thus truth slowly becomes established by scientific evidence.

Older hypotheses. Not long ago scientists spoke of the outer portion of the solid earth as the earth's "crust." They believed according to ideas then held that formerly the earth was hot enough to be in a liquid, or melted, state. They thought that as it grew cooler a crust or shell of solid rock slowly hardened over the melted interior. When the planetesimal hypothesis was proposed, however, the scientists who accepted it had to throw aside the idea that the earth was ever a melted, or molten, ball. They also had to throw aside the idea of an earth's crust as a solid layer covering a molten interior.

F. M. N. H.

FIG. 217. Where life began. It is believed by scientists that the first living things on the earth were exceedingly small plants which lived hundreds of millions of years ago in pools similar to some now seen in Yellowstone National Park. What evidence in this painting indicates that according to the planetesimal hypothesis the world at the time of this picture is millions of years old?

There are several reasons for concluding that the interior of the earth is solid. If the earth had a liquid center, earthquakes could not pass through it, as they are now known to do. Also, it is believed that if the earth had ever had a liquid center it would have stopped rotating ages ago. A simple experiment will help you to understand this last statement.

Experiment 46. Can you spin a raw egg on its end? Can you spin a hard-boiled egg on its end? Try to spin a raw egg. Are you successful? Repeat with another raw egg as a control. Are the results as before? Boil the two eggs for at least twenty minutes until they are entirely solid. Try to spin first one egg and then the other as a control. Are you successful with either or both? How does this experiment help to prove that the earth developed with a solid interior?

***Present-day hypothesis.** According to the planetesimal hypothesis, during the ages while the nebula slowly changed into

its present form, one of the larger knots thrown from the central body or sun became our earth. In the beginning it was much smaller than it is now. As meteors, meteorites, and dust fell upon it, it slowly grew in size. In this early growing stage its surface is thought to have been a loose and porous mass. The separate pieces and particles of rock and compounds of metals lay scattered about, just as they fell upon the earth as meteors, meteorites, and dust.

*At first the earth may not have been large enough to hold an atmosphere, or perhaps it was large enough to hold a thin atmosphere like that of Mars. But as it slowly grew in size from age to age its gravitational attraction increased. It became gradually able to hold a denser atmosphere which included some water vapor.

*Finally some of this water vapor condensed as rain. Some of the rain sank into the ground, some evaporated, and the rest flowed into hollows and formed pools. These pools were the beginnings of the oceans (Fig. 217).

As the mass of the earth increased, three different processes began to make changes in its surface. These three great processes, volcanism, gradation, and diastrophism, will be discussed in the next problem.

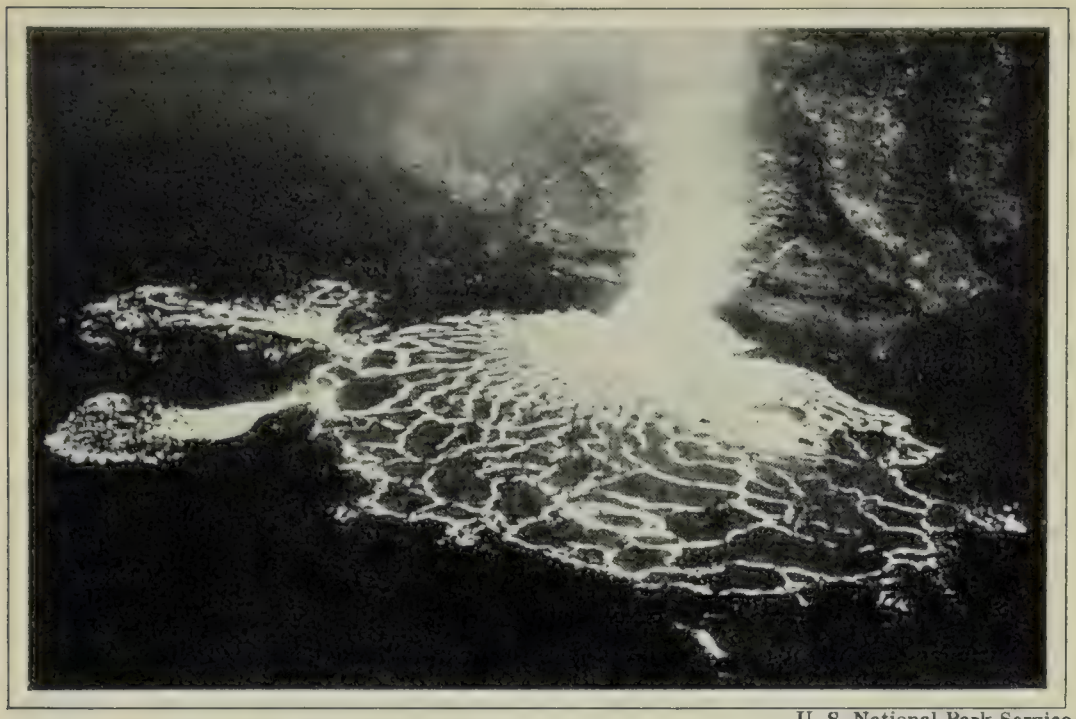
Self-test on Problem XIX–A. (*Do not write in the book.*) 1. According to the planetesimal *hypothesis*, the earth ages ago was *larger* than it now is.

2. According to the planetesimal hypothesis, the largest mass in the nebula from which the solar system developed became (1) the planet Jupiter; (2) a comet; (3) the asteroids; (4) the planet Saturn with its rings; (5) the sun; (6) the earth.

3. According to the planetesimal *hypothesis*, the earth's atmosphere in former ages contained *more* water vapor than now.

4. The larger a planet is, the *less* is its gravitational attraction, and consequently the *more* dense its atmosphere is likely to be.

5. The interior of the earth is believed to be composed of very hot matter which is (1) liquid; (2) solid; (3) half-liquid like warm tar; (4) gaseous; (5) a partial vacuum; (6) almost a complete vacuum.



U. S. National Park Service

FIG. 218. Eruption of a Hawaiian volcano (Kilauea) at night, Hawaii National Park. The lava is overflowing through a fissure, or crack, in the crater floor. What is the source of the light in this picture?

Problem XIX–B · What are the Processes which are constantly Producing Changes in the Earth's Surface?

***Volcanism.** The process of volcanism has to do with the effects of heat within the earth. According to the planetesimal hypothesis the interior of the earth in the beginning was not as it now is. As its mass grew its gravity increased. The pull of this increasing gravity on the matter of the earth caused more and more pressure. This pressure produced much heat. Additional heat was caused by the breaking down of radium and other similar substances. The pressure, however, was too great to allow materials to become liquid, no matter how hot they became, so long as the surface remained relatively unchanged. When shifts occurred in the earth's crust,[1] the pressure at some points was relieved. Where the pressures became sufficiently less,

[1] By "crust of the earth" is meant the outer portions of the solid earth. "Crust" is no longer used in the older sense of a shell-like outer covering of rock over a liquid core of melted rock.

some of the very hot solid materials were able to become liquid, or, as we commonly say of rocks made liquid by heat, "molten."

The molten material slowly worked its way toward the surface. One reason why it did this may be that the tidal action of the moon and the sun attracts the molten material inside the earth in the same way that it piles up the tides in the ocean. Another reason may be that when the rocks, minerals, and metals are melted, they expand somewhat and thus they become less dense than when they are solid. Whenever shifts of material, such as may be caused by folding, occur inside the earth, there is a tendency for lighter materials to be crowded toward the outside, because gravity pulls the heavier materials toward the center of the earth. Often the molten materials found their way to the surface through the cracks in the earth's crust caused by the shifting of materials.

*Volcanoes. After long ages some of the molten material within the earth broke through to the outside in violent eruptions (Fig. 21, p. 37) or in quiet flows of lava (Fig. 218). These were the first volcanoes.

By means of this process of volcanism layers of lava, or molten rock, were spread here and there over the earth's surface by volcanoes. But volcanism produced still other changes. Here and there great masses of volcanic rock were forced up through crevices, but they cooled and hardened before they quite reached the surface. Moreover, the volcanoes added gases to the atmosphere.

Gradation. When the earth had acquired an atmosphere, the higher parts of the surface began to wear away or be graded down. This grading process is known as gradation.

*The process of gradation has to do with the transporting of materials from one part of the earth to another by wind, running water, and moving ice. Through the process of gradation soluble[1] materials and sediment are transferred by running water from the highest land to the oceans, and less soluble materials and heavy solid bodies are left behind. Thus gradation cuts down the hills and builds up the valleys. Also it produces strata, or layers, of soil, many of which later turn to stone. In the course of ages the

[1] *Soluble* (sol'u bl): able to be dissolved.

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FIG. 219. The Grand Canyon of the Colorado River. What evidence of gradation is here? Self-test on Major Generalizations: What evidence is presented here in proof of the generalization "The earth is very old"?

process of gradation has produced vast changes in the earth's surface (Fig. 219). Gradation will be discussed in greater detail in the following problem.

Diastrophism. The process of diastrophism has to do with the warping and twisting of the surface as the materials of the earth are shifted under the pull of gravity. Three conditions have a tendency to cause diastrophism: (1) the uneven distribution of falling planetesimal material, (2) the shifting of materials by volcanism, and (3) the shifting of materials by gradation. These three conditions throw the earth out of balance. Gravity restores this balance by elevating some portions of the earth while at the same time depressing[1] other portions. During this rising and sinking there is always the tendency for the heavier materials to move nearer the center of the earth and to crowd the lighter materials upward. It is known that materials under the oceans are somewhat denser than are those composing the land areas. Hence diastrophism raises the continents higher and deepens the oceans.

[1] *Depress* (de pres'): to cause to sink down.

U. S. Geological Survey

FIG. 220. Calico Bluffs on the Yukon River, Alaska. What evidences of diastrophism are seen here?

***Mountains and earthquakes.** When continents are squeezed by diastrophism the borders become crumpled[1] up the most, so that mountain ranges are produced. During this process the rocks are so strained that rock masses sometimes break and slide over one another, causing earthquakes. Also, the moving and breaking up of rock masses gives the best chance for molten materials below to reach the surface. Hence volcanoes as well as earthquakes frequently occur in mountain ranges along the edges of continents.

Sometimes the wrinkling of the earth's surface tilts up and forces above the oceans great layers of sedimentary[2] rock (Fig. 220). It is known, for example, from the remains of plants and animals that are embedded in the rock, that parts of the state of New York have been elevated above the ocean and later depressed beneath it at three different times, probably millions of years apart.

[1] *Crumple:* to squeeze together, forming wrinkles.
[2] *Sedimentary* (sed i men'ta ry): formed of sediment.

***Summary of volcanism, gradation, and diastrophism.** The preceding paragraphs may be summarized thus: The surface of the earth has been undergoing constant gradual changes from its very beginnings. First its outer covering slowly deepened from age to age as the planetesimals fell. The more striking changes came later, however, (1) after the earth developed heat enough to produce *volcanism*; (2) after it had grown sufficiently to hold an atmosphere which made possible *gradation* by wind, ice, and running water; and (3) after its increasing gravity caused *diastrophism*, which wrinkled the land into mountains and lifted the sheets of sedimentary rock above the water.

*When after millions of years living things appeared on the earth, these also produced changes in the earth's surface in addition to all those which had been produced and are still being produced by the older causes.

Gradation and diastrophism compared. Gradation and diastrophism produce opposite effects. The final result of gradation is gradually to make the earth's surface level by carrying the land down into the ocean (Fig. 221). It is estimated that the Mississippi River alone deposits in the Gulf of Mexico on an average more than forty thousand tons of sediment every hour. It is estimated also that all the rivers in North America are lowering the average level of the continent at the rate of about an inch every seven hundred fifty years.

If gradation were to continue long enough without interruption, all the land now above the water would be carried into the ocean. There is interruption, however, in the form of diastrophism. Diastrophism wrinkles and crumples the ocean bottom as well as the land. It elevates certain areas and depresses other areas elsewhere.

For a long period of time gradation may go on changing the earth's surface faster than diastrophism; then diastrophism may produce the greater changes. For example, about one fourth of the earth's surface is now above water. But ages ago there were times, after the process of gradation had been going on for thousands of years without interruption, when only about one eighth or even one twelfth of the earth's surface was above the level of the oceans. Just at present diastrophism is believed to be producing

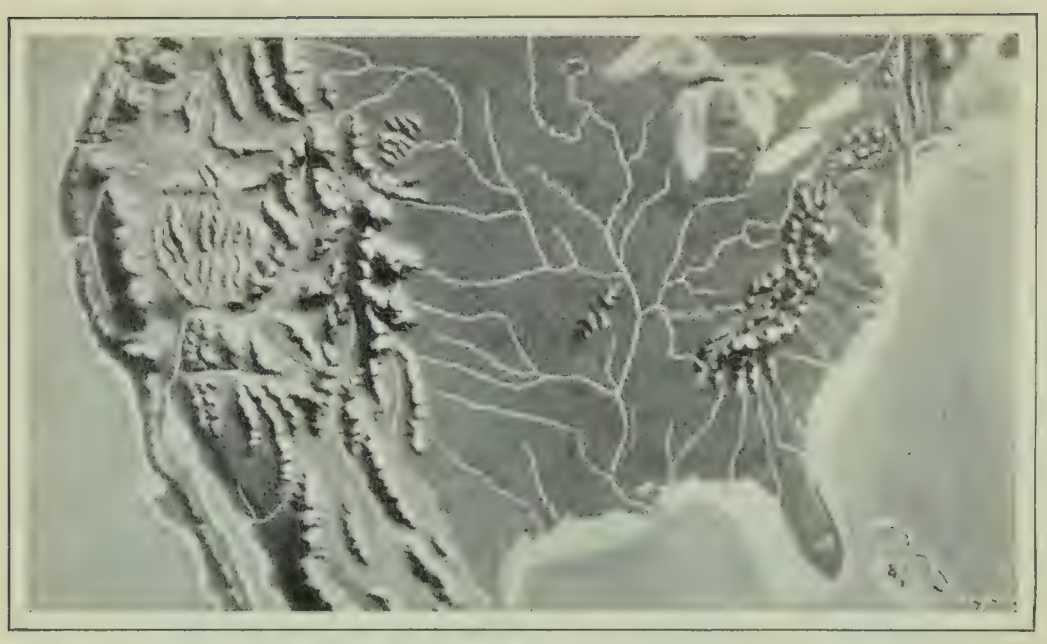


FIG. 221. A relief map showing land levels and sea-bottom levels. What evidences of gradation and diastrophism are seen here?

greater changes than gradation, with the result that the land areas are growing faster than they are being worn down. But from age to age diastrophism and gradation balance each other well enough so that about the same area of land remains above water.

Self-test on Problem XIX–B. (*Do not write in the book.*) 1. According to the planetesimal hypothesis, the more the earth increased in size the *higher* became the temperature in its interior because of *decreased* pressure.

2. The materials in the interior of the earth became *molten* when the pressure was *increased.*

3. According to the planetesimal hypothesis, there were *many* volcanoes during the earliest stages of the earth's growth.

4. In the earliest stages of the earth there was *little* gradation.

5. If it were not for *gradation*, all the land would finally be carried below the surface of the *ocean.*

6. *Volcanism* causes single mountains to become higher, while *gradation* causes mountain ranges to become higher.

7. Valleys are made deeper by *gradation.*

8. Gradation and diastrophism are taking place *most* of the time.

Problem XIX–C · How do Weathering and Erosion Produce Gradation?

What are weathering and erosion? Gradation is the result of two processes, weathering and erosion. Weathering is the process of breaking up and changing rock into soil. If it were not for the process of weathering, the surface of the land would be mostly unchanging bare rock. Erosion scrapes, scours off, and carries away portions of rock and soil at and near the earth's surface.

*The agents of weathering are usually divided into two classes: mechanical agents and chemical agents. The mechanical agents produce only physical changes in the surface rock. They break up the rock into smaller and smaller bits. The common mechanical agents are freezing water, sudden changes of temperature, growing plants, gravity, and animals. The chemical agents produce chemical changes in the rock. They change it from rock to other substances. Chemical changes also result in reducing the rock to smaller particles. Chemical agents are substances in the air and substances given off by plants.

Agents of weathering: 1. Freezing water. ***Experiment 47.*** Does water change in volume when it freezes? Fill a small thin-glass bottle or test tube with water. Insert the cork so that the bottle is exactly full when the cork is in. Tie the cork so that it cannot slip out. Immerse the bottle or tube in a pail containing cracked ice and coarse salt in the proportion of two or three handfuls of ice to one of salt. Leave the tube or bottle completely buried in this mixture for an hour or so. Then examine it. Answer with a complete sentence the question asked at the beginning of this experiment.

Rain water is pulled by gravity into cracks and crevices[1] in the rocks. Later, if this imprisoned water freezes, it expands with enormous force, splitting off flakes and sometimes huge pieces of rock.

2. Sudden changes of temperature. ***Experiment 48.*** Does either the sudden heating or the rapid cooling of rocks produce changes in them? Secure a number of samples of different kinds of rocks, such as you can pick up in a few minutes from a gravel pit or a stream

[1] *Crevice* (krev'is): a small crack or opening.

bed. Using tongs, hold each of these in turn over a lighted burner. Are any of the samples affected by the sudden heating? When each is very hot, plunge it into cold water. Are any affected by the sudden cooling?

Both the rapid heating and the sudden cooling of rock cause unequal expansion and contraction.[1] Sometimes rock which is heated by the sun and quickly cooled after the sun goes down is broken up in this way.

Fig. 222. What evidence that trees are agents of weathering is here?

3. Growing plants. Trees growing in crevices sometimes exert sufficient pressure with their roots to split off pieces of rock (Fig. 222). Perhaps you have observed a concrete sidewalk which has been pushed up and broken in this way. Even small and weak plants can accomplish this where the structure of the rock has been weakened by the chemical action of the air or of ground water.

4. Gravity. The constant pull of gravity on rocks sometimes causes them to break and fall. In falling they may shatter other rock, making it possible or easier for other agents of weathering to act upon the rock.

5. Animals. Some animals, especially man, dig into the soil and rock, exposing them to the agents of weathering. Such animals must therefore be classed as agents of weathering.

The chemical agents of weathering: 1. The chemical action of the air. Carbon dioxide, oxygen, and other substances in the air combine chemically with substances in some rocks, causing the rocks to crumble.

[1] *Contraction* (kon trak'shun): act of becoming smaller by drawing together.

2. The chemical action of plants. Plants give off carbon dioxide and other substances from their roots and from decaying leaves. These substances attack the rocks and, by combining chemically with them, often weaken and crumble them.

U. S. National Park Service

FIG. 223. "Temple of the Sun," Carlsbad Caverns National Park, New Mexico. **Special Report:** The formation of stalactites and stalagmites. (Consult a textbook of geology or of physiography, or an encyclopedia)

How erosion assists weathering. Thus weathering slowly goes on, continually breaking up the rock into soil. But if it were not for erosion, which removes the products of weathering, the weathering would finally stop, because it would produce a sufficient covering of soil over the rock to protect the rock from further attack. Erosion carries away the weathered materials and exposes the rock for further weathering.

***Agents of erosion: 1. Ground water.** Whenever it rains, some of the water sinks into the earth and becomes ground water. Ground water is never pure water. As it passes through the air it dissolves some carbon dioxide and oxygen. As it sinks through the ground it dissolves certain substances. If it becomes heated by coming in contact with volcanic rock, it is thus able to dissolve still greater quantities of substances. When the ground water containing all these substances in solution comes in contact with the rocks, it dissolves some of them and carries them away to the streams. Thus part of the dissolved minerals finally reach the ocean. The Mammoth Cave, the Carlsbad Caverns (Fig. 223), and similar limestone caves resulted from erosion of this sort.

*2. **Running water.** *Experiment 49.* Does a stream furnish evidence of erosion? Fill a glass with the yellow water of a stream after a rain. Put it aside for several days where it will not be disturbed. Does the color of the water change? Can you account for the phenomena you observe?

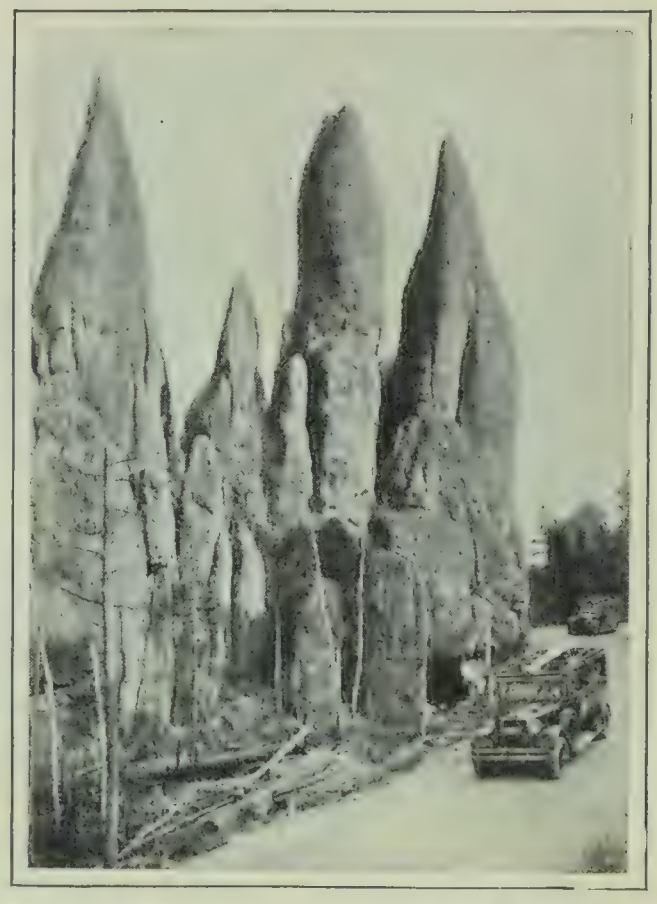


FIG. 224. Evidences of erosion in the Black Hills, South Dakota. **Exercise on Scientific Method (Making Hypotheses):** How many reasons can you suggest to account for the fact that some parts of the rock are eroded more than others?

When rain falls upon a land surface, the water is pulled toward lower levels by gravity, forming the streams and rivers. The steeper the slope the faster gravity makes the water flow. As it flows over and through the loose weathered material, it carries part of this material with it. Thus the water flowing in gutters and streams is yellow with particles of mud after a rain. The soil and rocks which the stream carries, especially heavier stones which it rolls along the bottom, increase its friction, so that to the load of weathered material which it is already carrying, the stream adds other materials scraped and scoured from the stream bed.

Rapidly flowing water can carry large amounts of soil and other materials. In the more level country, as the streams approach the oceans or lakes into which they empty, the water flows more slowly and deposits part of its load of eroded soil and gravel. This fills up the stream beds and may cause the streams to break over their banks into the surrounding country. When this occurs

people, farm animals, and wild animals may be drowned, farm and garden crops may be destroyed, forests may be killed, and crops may be smothered under a deposit of fine soil. To prevent such damage, the banks of streams have been built high in the form of heavy walls called dikes or levees. The banks of the Mississippi River are thus protected for long distances by levees.

3. Winds. The friction of wind as it blows across the land causes the air to pick up and drag along bits of weathered materials such as grains of dust and sand. When these solid particles are blown against rock, the rock is eroded faster than the wind alone could do it (Fig. 224).

***4. Waves, tides, and currents.** The friction of the wind as it moves across the surface of the ocean produces waves, which dash against the shores with enormous force. The tides and shore currents likewise constantly scrape and scour the shores. The surface waves, the tidal waves, and the currents cut under the cliffs at the level of the water, breaking, gnawing out, and carrying away the rock materials. When the cliffs have been sufficiently eroded at the bottom, gravity pulls down the upper portions. The cliffs are thus slowly cut back, and are deposited bit by bit in the ocean.

***5. Glaciers.** When more snow falls in the polar regions and in the mountains in winter than melts during the summer, the snow slowly piles up in the upper valleys. Gravity packs it down, finally changing the snow into ice. Thus a glacier is formed (Fig. 99, p. 149). The glacier is slowly pulled down the valley by gravity. It travels on the average only a few feet a day. If the glacier is big enough to cover a whole region, it may take a year to flow only a few feet. The glacier digs its valley deeper and broader as it slowly moves down. It does not often reach the ocean, but deposits its eroded load when a point is reached where the melting at the end just balances the downward flow of the glacier (Fig. 225). Some of the eroded rock is carried off at once by the streams formed by the melting glacier. The rest may remain for thousands of years where it was left by the melting ice. Bit by bit, however, it is weathered down and finally carried by rills to the streams and by the streams to the ocean. The streams of lower Canada and the upper United States are still transporting the material deposited by the great North American ice sheet (Fig. 226).

U. S. Geological Survey

FIG. 225. The lower end of a glacier. What evidence is shown of the transportation of rock by the glacier? What evidence is there of the melting of the glacier?

Self-test on Problem XIX–C. (*Do not write in the book.*) **1.** If the earth had never had an atmosphere there would now be *little* soil on the *surface.*

2. *Diastrophism* includes both weathering and *erosion.*

3. If it were not for *weathering, erosion* would finally cease.

4. *All* agents of *weathering* produce their effects as a result of moving over the earth's surface.

5. *Much* of the soil which was formerly on the hills is now in valleys because of *weathering.*

6. Select from the following list the agents of weathering and of erosion: (1) glaciers; (2) winds; (3) changing temperatures; (4) ocean and lake waves; (5) freezing water; (6) man; (7) growing plants; (8) tides; (9) carbon dioxide; (10) oxygen; (11) ground water; (12) gravity.

Problem XIX–D · Why is it Important to Understand Weathering and Erosion?

How do weathering and erosion affect the soil? We have just learned that soil is formed from the solid rock, or bedrock, by the action of weathering and erosion. Also we have learned that weathering and erosion are the results both of natural forces and of the activities of living things. Soil is therefore a mixture of inorganic and organic materials (see Glossary). Let us see how this mixture is formed.

FIG. 226. The North American ice sheet. *A*, *B*, and *C* were the centers from which it spread. **Self-test on Scientific Principles:** What evidence is here to support the principle "The earth's surface is constantly changing"?

How is soil formed? If we examine the surface of a rocky cliff, we usually find no soil on it. Careful examination, however, will enable us to find some plant growth even on the rock. Gray or reddish-brown plants called lichens adhere to the surface and grow into scalelike masses (Fig. 227). During their growth these plants dissolve a little of the surface of the rock, so that when the masses of the plant later die and fall from the rock some rock particles fall with it. New lichens then grow in the same way. The old lichens decay, and they and the rock materials become the soil in which other plants such as mosses, ferns, and very young plants of still other kinds may grow. New growths of plants and animals which live in the soil constantly make their additions of humus.[1] At the same time the air, heat energy, and the other nonliving agents of weathering are breaking up the rock. Thus the living and the nonliving agents of weathering are constantly acting together in making soil. In almost any region of rocks one may see various stages in the never-ending processes of soil-making.

[1] *Humus* (hu'mus): organic material in the soil resulting from the decay of plant and animal matter.

FIG. 227. The white patches are lichens. What other weathering agents besides lichens are at work here?

The products of decay and the broken rock are gradually eroded and are spread over the valleys. When deep beds of rich soil have been formed, the kinds of plants which started the process are no longer found, but in this soil there now are plants and animals that cannot live on rocks with the small amount of soil found there at the beginning of soil-making.

Composition of soil. Soils in different places will have different compositions. The materials composing them are of different kinds and sizes, and these are mixed together in different ways. The inorganic materials range in size from gravel through sand and silt[1] to particles of clay less than a thousandth of an inch in diameter. Clay soils are compact and heavy. Soils made chiefly from decay of plants and animals are loose and light.

The organic matter, or humus, varies widely not only in amount but also in size of particles. Soils consisting of a mixture of inorganic materials and humus are called loams. The larger the amount of organic matter in loams, the less they weigh per cubic

[1] *Silt:* fine particles of earth that settle to the bottom of water; or a deposit of such soil.

Michigan Education Journal

FIG. 228. Double Turnip Rock on the shore of Lake Huron, Michigan. Where should you expect to find residual and transported soils here?

foot. It is for this reason that loams rich in humus are called light soils. In swamps, or in areas that once were swamps, the amount of decayed vegetation is sometimes so large that the soil is almost like chaff, and will even burn when set on fire.

Residual and transported soil. Soil that remains above the bedrock from which it was formed is called residual[1] soil. Residual soil is always weathered soil. Soil that has been carried from the place where it was formed and deposited somewhere else is called transported soil. Transported soil is always eroded soil (Fig. 228).

We have learned that the bedrock undergoes chemical changes during the process of weathering. Hence residual soil is different in substance from the bedrock from which it was formed, but it is uniform at any given location. Residual soils differ greatly from one another also, because the bedrocks from which they are formed differ greatly.

Transported soil is usually very different from the rock upon

[1] *Residual* (re zid'u al): remaining in its original place or the place where it was formed.

which it rests, because it consists not only of weathered soil from a wide variety of places but also of portions scoured and scraped from all the rocks over which the agents of erosion passed while transporting the soil.

Causes of differences in transported soils. Other differences in the nature of transported soil found in different places are due to the nature and actions of the various agents of transportation (erosion).

Experiment 50. Does water sort soil? Put into each of two fruit jars several handfuls of dirt containing fine and coarse particles, including sand and gravel. When each jar is half full, fill it the rest of the way with water. Put on the covers, then shake one jar vigorously until the water is all through the soil. Quickly place both jars upright side by side and do not disturb them for a day or so. Explain your answer to the question asked at the beginning of this experiment. Why were two jars used instead of one?

Experiment 51. What can a magnifying glass show us about soil? With a magnifying glass examine a handful of soil. How many different kinds of particles do you see? Do you find any humus? Do you infer that the soil is light or heavy? Explain. Examine sand grains to see whether the corners are sharp or rounded. Can you tell from their sharpness or roundness whether they are residual or transported?

Sorted and unsorted soils. Light winds can pick up dust and finer particles, and strong winds can transport sand. Slow-moving streams can carry fine particles only. Swift streams can transport gravel and even rocks. When running water has its speed reduced by running from a hillside onto level ground, it drops its load in a mixture of fine and coarser pieces. When running water flows into the still water of a lake or ocean, the heavier particles are dropped nearest the shore and the finer particles are carried farther, sometimes into deep water. It is evident, then, that soil resulting from wind erosion and water erosion is to some extent sorted. The soil at the end of glaciers, however, is unsorted. Why?

The result of all these different factors is that we sometimes find uniform beds of soil, such as sand, clay, or gravel, near other uniform beds which are entirely different; or we may find all sorts of mixtures of the various kinds of soil.

U. S. Forest Service

FIG. 229. Erosion on a Mississippi farm. How could this destruction of fertile land have been prevented? Can anything now be done to save what good soil remains?

Fertility of transported soil. Transported soil, whether deposited by glaciers or by rivers, is usually fertile and suitable for agriculture. The great civilizations three thousand years ago were confined almost entirely to the flood plains of rivers. The thickly populated regions today are likewise in or near great agricultural regions, which are fertile because they are covered with a rich layer of transported soil.

Erosion increased by man. It is estimated that on the average the agents of weathering produce a foot of residual soil in the United States every ten thousand years. This seems very slow. Yet weathering produces residual soil faster, on the average, than it is transported away by the agents of erosion. We should expect, therefore, to find fine soil above the bedrock generally except on the steeper slopes. But man upsets the usual course of nature. By cutting away the forests and by plowing the land for his crops he exposes the soil to erosion. The result is that the soil erodes away so much faster than it is formed by weathering that over large areas all the fine fertile soil is gone and the remaining land is almost useless (Fig. 229).

Keystone View

FIG. 230. *A*, the approach of the great storm of May, 1934, at a town west of the Mississippi River; *B*, the same dust storm over New York City a few days later. Why did this storm travel to the Atlantic rather than to the Pacific coast?

Serious wind erosion. In certain farming regions of the Middle West which are sufficiently level so that there is relatively little loss of fertile soil from water erosion, the removal of the native trees and grasses has exposed the soil to winds. At times of drought heavy winds may blow away fine soil particles in dense clouds of dust. Extremely severe dust storms of this nature occurred in parts of Colorado, Oklahoma, Texas, South Dakota, and Nebraska during 1934 and 1935 (Fig. 230). These dust storms sometimes last for several days and do great damage. Many farm animals and even human beings may die from breathing the dust. In such storms the removal of the finer soil reduces the fertility of the farms. Some areas, indeed, have thus been rendered unfit for future crops of grain. Such damage is not likely to be stopped except by replanting the trees and grasses which help to hold the soil.

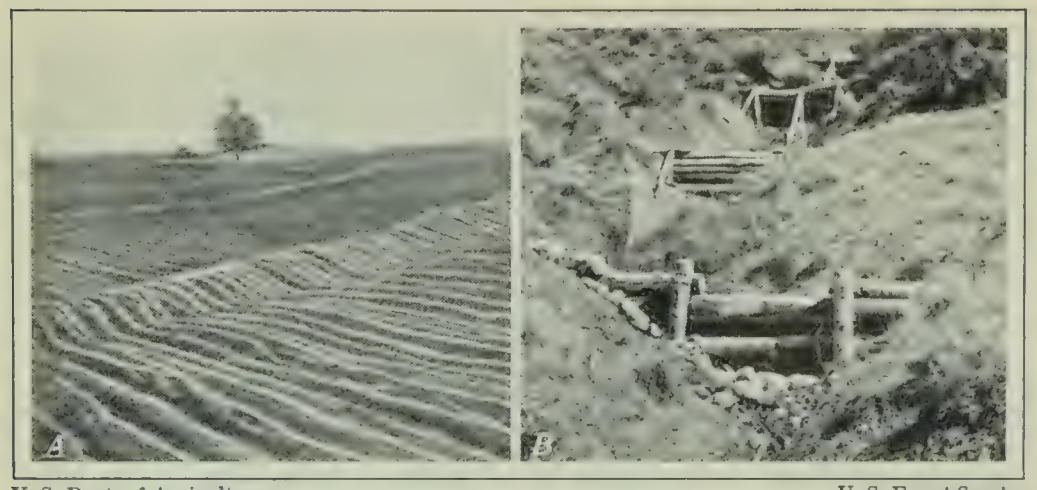
Reducing erosion. As the population of the earth continues to increase, however, there is more and more need to conserve the fertile soil. Men have learned several ways by which water erosion may be decreased. They have found (1) that erosion is less rapid when they plow across the slopes instead of up and down; (2) that they can decrease erosion by the methods shown in Fig. 231; (3) that the more deeply and the more frequently they till the soil the slower the water erosion will be, because the soil will absorb more rain, thus reducing the amount which runs rapidly away over the surface; (4) that soil erodes more slowly if it is covered with crops, grass, or forests. There is a pressing need to find equally effective ways of reducing wind erosion of agricultural land. Many experiments are being conducted in an effort to find the best kinds of grass to plant on the farming regions of the Middle West which have suffered most severely from dust storms.

Self-test on Problem XIX–D. (*Do not write in the book.*) 1. *Organic* soil is composed entirely of decayed rock.

2. Deep beds of soil result from *weathering.*

3. Weathered soil is *more* likely to be sorted than eroded *soil.*

4. The soil on the slopes of the famous volcano Mt. Etna is very fertile. It is chiefly *eroded* soil.



U. S. Dept. of Agriculture U. S. Forest Service

FIG. 231. *A*, preventing rapid erosion on a North Carolina farm; *B*, reducing erosion with log and brush dams made by the CCC in San Juan National Forest, Colorado. **Special Report:** Erosion reduction projects in your state or province. (Consult your state or provincial department)

5. Soil would contain *little* humus if there had never been living things on the earth.

6. Soil in the dry bed of a lake is probably *transported* soil.

Self-test on Scientific Principles. 1. Can you explain the meaning of this principle: "Several different sources of energy result from gravitation"?

2. Can you explain the meaning of this principle: "The present is the key to the past"?

3. Can you explain why this principle is true: "In general, the farther below the surface a stratum of rocks lies the older it is"? Can you explain why this statement is true "in general" but not always?

4. Can you explain this principle: "Gradation, diastrophism, and volcanism are the effects of gravitation"?

Self-test on Major Generalizations. What evidence can you state from this chapter which supports the major generalization "The earth is very old"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why do rocks in the beds of mountain streams have rounded corners, while rocks of mountain slopes do not?

2. The region of the Grand Canyon in Arizona is still rising, though the Colorado River has already cut the canyon more than a mile deep.

To what is the rising of the region due? What would finally happen if this region ceased to rise and began slowly to sink?

3. Why are concrete roads often cracked during the winter?

4. Could animals, especially man, be considered as agents of erosion?

5. Mountain streams usually have V-shaped valleys, and valley streams usually have broad, U-shaped valleys. Explain why this is true.

6. Why is residual soil always weathered soil? Why is transported soil always eroded soil?

7. Why are stucco houses often found unsatisfactory in climates where the winters are cold?

Special Reports. 1. Find out all you can about the wonders of the Carlsbad Caverns, New Mexico; the Mammoth Cave of Kentucky; the Cave of the Winds, Colorado; the limestone caves of Virginia or Oregon; or some other limestone caves.

2. Before the planetesimal hypothesis became so generally accepted, the most widely accepted hypothesis to account for the formation of the bodies in the solar system was the nebular hypothesis. What was this hypothesis?

3. Give accounts of some of the world's greatest volcanoes; for example, Etna, Vesuvius, Mont Pelée, Katmai, Asamayama, Krakatao, the Hawaiian volcanoes, and the Valley of Ten Thousand Smokes in Alaska.

4. The only volcano which has recently erupted in the United States is Mt. Lassen, in Mount Lassen National Park, California. When did it last erupt and what are its characteristics?

5. Name several great cities which are located on rivers. What is the relation of rivers to the development of great cities?

6. Discuss the serious dust storms which occurred during some year, as during 1934 or 1935.

7. Discuss recent earthquakes that have occurred in the United States or Canada.

8. How much of E. Bulwer-Lytton's celebrated story *The Last Days of Pompeii* is founded on fact? What is to be seen today on the sites of the old Roman cities Pompeii and Herculaneum?

Books for Reference

Bradley, J. H. The Earth and its History. Ginn and Company, Boston.
Fraser, C. C. Secrets of the Earth. Thomas Y. Crowell Company, New York.
Grew, E. S. The Romance of Modern Geology. J. B. Lippincott Company.
Houston, E. J. The Wonder Book of Volcanoes and Earthquakes. Frederick A. Stokes Company, New York.

Chapter XX · Some Natural Resources in the Earth

Questions this Chapter Answers

What kinds of energy does the earth provide?
What are the cause and the characteristics of geysers?
What are the nature and the sources of coal, petroleum, gasoline, and natural gas?
To what extent are these sources of energy being exhausted?
What are the characteristics of minerals, rocks, and ores?
What is the nature of some of the more important metallic and nonmetallic minerals?
What are some important characteristics of the three great classes of rocks?
What are the nature and the importance of fossils?
What are the uses and the relative values of building materials found within the earth?

Problem XX–A · What Sources of Energy does the Earth's Interior Provide?

***Stores of energy and raw materials.** Science has taught us how to use two kinds of substances from the storehouse of the earth: (1) those which furnish energy and (2) those which serve as raw materials to be made up into various articles we need. Although scientists have already discovered many different sources of energy, it is very unlikely that they have yet discovered all that the earth has in store for us. Also, it is certain that they will continue to learn how to make new and valuable things out of raw materials which are now considered worthless, just as they have recently learned to make many useful articles out of cornstalks and corncobs.

*Among the sources of energy which the earth provides and which man has already learned to use are these:

1. The mechanical energy of moving air, which is used to drive boats, to turn windmills, and to carry balloons.
2. The mechanical energy of running water, which is used to turn the wheels of mills and to generate electricity.

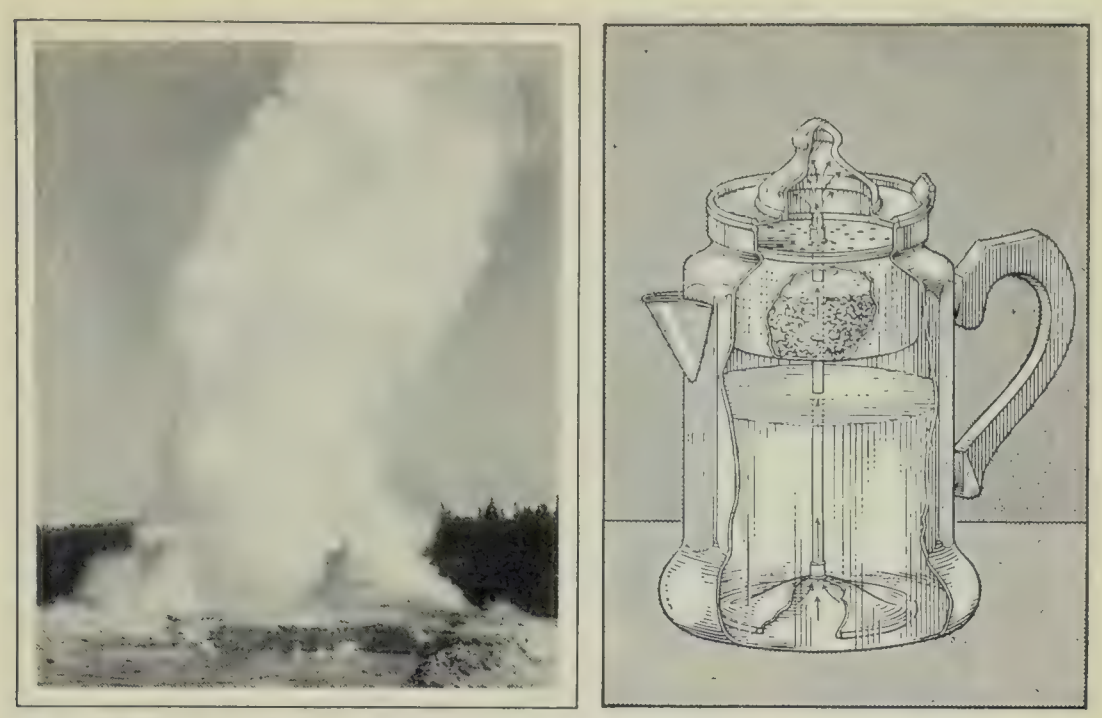


FIG. 232. The Castle Geyser, Yellowstone National Park, and a coffee percolator. After reading the explanation of the geyser, can you explain why the coffee percolator spouts hot water?

3. The chemical energy of various kinds of foods.
4. The mechanical energy of sound waves, which are used for communication and music.
5. The chemical energy of various fuels.
6. The energy of light, which serves us in so many ways.

*Among other sources of energy that may be found on the earth, but that man has not yet learned to use on a large scale, are the mechanical energy of the tides, the direct heat energy of the sun, and the heat energy in the interior of the earth.

Volcanic energy: geysers. Hot springs are found in many parts of the world, even in latitudes almost as far north as the polar regions. The water of these springs is heated by hot rocks just below the earth's surface. Visitors to Yellowstone Park and to certain parts of California see not only hot springs but wonderful geysers. These are natural fountains which every little while spout boiling water and steam many feet into the air. Old Faithful is the most famous of these.

*These geysers spout for the same reason that hot water spouts up in a coffee percolator (Fig. 232). The water from a

geyser spouts out of the upper end of a long, narrow, chimney-like opening in the rock. Water slowly flows or drips into this opening, just as water finds its way through the sides of a well, partly filling it. At the bottom are hot rocks. You will remember that water begins to boil when it becomes 212° F. provided the pressure on the water is the normal pressure of the atmosphere. When the pressure is greater than normal atmospheric pressure, however, the water must be made hotter than 212° F. before it will boil. The weight of the column of water in the geyser pipe makes the pressure on the water at the bottom greater than the normal pressure of the atmosphere. Consequently the water does not begin to boil at 212° F. but remains liquid, though it continues to get hotter. Finally it becomes hot enough to boil even though it is under great pressure. As soon as some of the water at the bottom is changed to steam, it expands rapidly and pushes some of the water out at the top. Immediately the pressure on the water at the bottom becomes less because there is not so much water above it. At once the water at the bottom begins to boil more violently because the pressure on it is decreased. Steam is therefore generated so rapidly at the bottom that the water above is forced out with great violence, sometimes to a height of two hundred feet.

*Coal. Coal is composed mostly of carbon. It also contains hydrogen, oxygen, and other substances, including ash.

*Ages ago the coal that we now burn grew as trees and other vegetation in swampy land (Fig. 233). As the centuries passed, many of the trees died. Thus a thick layer of decaying vegetation was slowly formed in the swamp. Then the swamp in which this vegetation grew was lowered by diastrophism. The waves and currents, by erosion, brought down sand and clay and covered the vegetable matter with these. Later the covering bed of sand and clay was raised enough by diastrophism to let vegetation grow upon it. This growth in turn was lowered by diastrophism and covered by sand and gravel brought by erosion. In this way often several layers, or strata, of vegetable matter were buried under strata of sediment. The vegetable matter was probably partly changed to coal by the action of bacteria, and the heat and pressure due to the weight of the sedimentary strata over it completed the

N. Y. State Museum and J. A. Glenn

FIG. 233. A coal-age forest. What evidence is there that at a still earlier age the region pictured was under water?

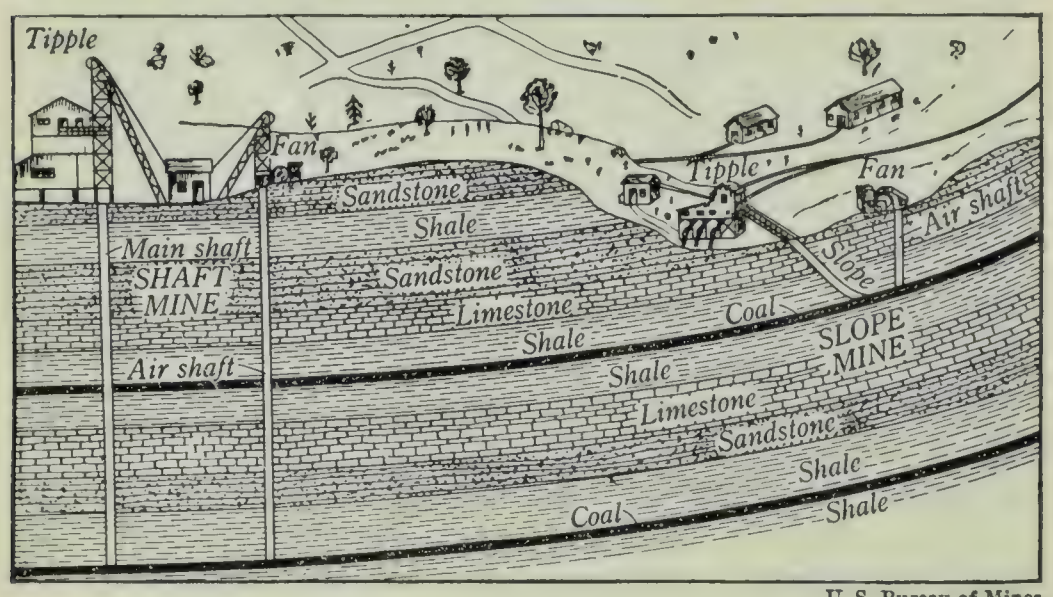
change. Some deposits of coal are of very great thickness. Layers two hundred feet thick have been found in France and India.

Diamonds are of practically the same composition as coal. They are pure carbon which has been formed into crystals under enormous pressure. Jet beads are made from certain deposits of cannel coal mined in England and Spain.

How extensive are coal deposits? Coal is found in every continent of the world, even in the polar regions. Africa is thought to contain less than the other continents. Vast deposits are found in every country of North America. Coal is mined extensively in the great manufacturing regions of the East, in the Middle West, in portions of the South, and in the Rocky Mountain states (Fig. 234), but most of the Atlantic, Pacific, and Gulf states lack coal deposits. Most of the coal in this country is bituminous, or soft, coal. Practically all the anthracite, or hard, coal is mined in eastern Pennsylvania.

The coal problem. It was formerly thought that the United States had more coal than would ever be used. It is realized now, however, that the precious coal supplies are fast disappearing. It is estimated that at the present rate of use the deposits of both anthracite and bituminous coal in the United States will be ex-

hausted within a hundred years. At present less than two thirds of a ton of coal in the mine finally reaches the consumer. About



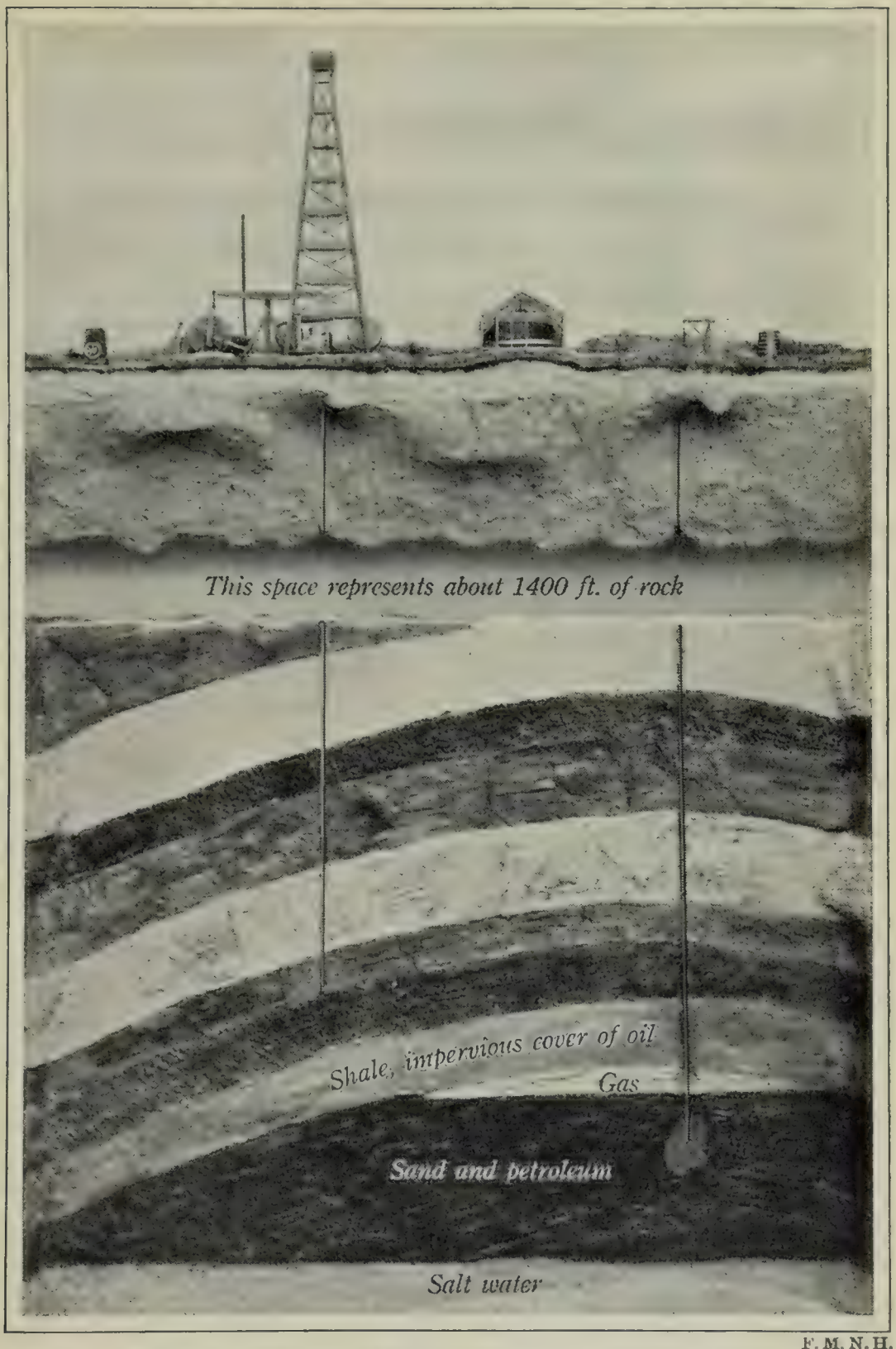
U. S. Bureau of Mines

FIG. 234. Diagram of a coal mine. What evidences of diastrophism and gradation are here?

one third is lost in mining and in transportation. Of the coal that is burned only about one third results in useful work. Thus only about two ninths of every ton in the coal vein is finally used. Less wasteful ways of mining and of handling coal should therefore be devised. Also more efficient engines and furnaces should be invented, so that a greater percentage of the potential energy in the coal can be transformed into useful heat, light, electrical, and mechanical energy.

*Petroleum. Petroleum, or crude oil, is a thick liquid which may be pale-yellow, red, brown, or black, though it usually looks greenish-black. It is believed to have been formed by the slow decomposition[1] of ocean plants and animals buried ages ago under layers of sediment. It is found in porous rock (usually coarse sandstone, conglomerate, or limestone), which it saturates in much the same way that water saturates a sponge. Sometimes these oil deposits are near the surface. Sometimes they are at a depth of several thousand feet. A nonporous layer of rock, such as shale, above the oil-bearing rock, keeps the oil from escaping (Fig. 235).

[1] *Decompose* (de kom poze′) : to break down a substance into simpler substances. *Decomposition* (de kom po zish′un) : the process of decomposing.



F. M. N. H.

FIG. 235. Diagram of oil wells. The one on the left has not yet been driven into the oil-bearing sands. Self-test on Major Generalizations: What evidence is here that "The earth is very old"?

Ewing Galloway

FIG. 236. *A*, an oil gusher at Long Beach, California; *B*, an oil field under the lake near Shreveport, Louisiana. What causes the oil to spout from the top of the pipe in *A*? How is it possible for oil wells to be beneath the bed of the ocean (as off the coast of Southern California)?

Securing the petroleum. A hole from six to eight inches in diameter is drilled through the nonporous rock into the oil-bearing rock. Sometimes when the oil is reached it spouts out of the top of the pipe. Such wells are known as "gushers" (Fig. 236, *A*). The oil is probably forced from gushers by the pressure of natural gas above the oil. This acts upon the oil in much the same way as does the compressed air in the tank of a compressed-air water system. Sometimes the oil does not rise to the surface and has to be pumped.

The use of petroleum. Petroleum was used to some extent as far back as we have historic records. Early in the nineteenth century it was used in this country as a medicine. The growth of the petroleum industry did not begin in the United States, however, until August, 1859, when a well flowing twenty-five barrels a day was dug on Oil Creek, Pennsylvania. Extensive oil fields have since been discovered and developed (Fig. 236, *B*) in Ohio, Indiana, Illinois, Oklahoma, Texas, California, and many other states, and in Canada. It has been estimated that from 1860

almost up to the present time as much petroleum has been taken from the earth during every nine-year period as in all the preceding years put together.

Gasoline. Gasoline is the most valuable product secured from petroleum. Petroleum in its natural, or crude, state is not yet very largely used. It has some use as a road covering to lay the dust and as a fuel. The latter use is rapidly increasing. The products which chemists have learned to make from crude petroleum are of the greatest value.

*Chemists have learned that petroleum is a mixture of many valuable chemical compounds of carbon and hydrogen, called hydrocarbons. These different hydrocarbons are separated from the crude petroleum by distilling it in much the same way as water is distilled. The most valuable of the hydrocarbons are gasoline, kerosene, benzine, naphtha, petroleum ether, gas oils, lubricating oils, vaseline, and paraffin. Each of the hydrocarbons in the petroleum boils at a different temperature from all the others. When the petroleum is heated, the hydrocarbon which has the lowest boiling point boils off from the petroleum first. Most of the other hydrocarbons, which boil at higher temperatures, are left behind as liquids. The temperature is usually kept for several hours at the boiling point of the first hydrocarbon until it has practically all boiled off. Its vapor is cooled and condensed, then purified. The temperature of the remaining liquid is then raised to the boiling point of the next hydrocarbon. It is secured in the same way as the first. Thus each of the valuable hydrocarbons is vaporized, collected, condensed, and purified in turn. What is left is sold for fuel oil, though it still contains asphalt or paraffin, which can be obtained from it. Such fuel oil is used for heating our homes and office buildings and as fuel for merchant ships and even battleships.

Natural gas. Natural gas is found in more than half the states of the Union. It is usually found in regions where petroleum occurs, and is often obtained from petroleum wells. Enormous quantities of it are being allowed to escape from the ground unused. It has been estimated that unless new supplies are discovered the known supplies will be exhausted within another twenty-five years.

Self-test on Problem XX–A. (*Do not write in the book.*) **1.** Man secures from the earth stores of raw materials and other materials which furnish __(?)__.

2. Geysers are most likely to be found (1) in great river valleys; (2) on ocean beaches; (3) in volcanic regions; (4) near artesian wells; (5) in the temperate regions; (6) near lakes and swamps.

3. *All* coal beds were once under water.

4. Coal consists *chiefly* of *animal* material.

5. The most useful product obtained from petroleum is (1) paraffin; (2) fuel oil; (3) vaseline; (4) benzine; (5) gasoline.

6. The boiling temperatures of fuel oil and asphalt are *higher* than the boiling temperatures of the substances which are secured earlier in the process of distilling petroleum.

7. Pockets of natural gas are *often* found at the *bottom* of deposits of petroleum.

Problem XX–B · What are the Properties of Some Valuable Minerals?

Minerals, rocks, and ores. The raw materials which man secures from the earth are mostly minerals and rocks. A mineral may be either a single element, like gold or iron, or a compound of two or more elements, like clay or quartz. When it is composed of more than one element, the proportion of each element composing the compound is the same wherever the sample of the mineral is found. Thus, pure quartz is always a compound of oxygen and silicon in the same proportions. Consequently one sample of a mineral has the same properties as any other sample of the same mineral. The metals are all of mineral origin.

*A rock is usually composed of two or more minerals not combined chemically but mixed. The proportions of the minerals composing the rock may vary considerably in the same kind of rock. Thus, a sample of common granite contains the three minerals quartz, feldspar, and mica, but the particles of each of these minerals are easily seen to be separate in the granite. Furthermore, a piece of granite may contain only a little quartz in proportion to the amount of mica and feldspar, or it may be half quartz.

An ore is a rock or mineral containing one or more metals. The mineral ores are usually composed of a metal combined chemically with oxygen or sulfur.

FIG. 237. Copper bars awaiting shipment in the "copper country," Michigan. Why is copper a better metal than iron for window screens, and for nails and sheets for the bottoms of ships?

*Metallic[1] minerals. ***Experiment 52.*** What are some of the characteristics of certain common rocks and minerals? Secure, if you can, at least two specimens of each of the following minerals: quartz, feldspar, mica, calcite, hornblende, gypsum, halite, hematite, and iron pyrites. Similarly secure, if you can, at least two specimens of each of the following rocks: granite, marble, limestone, shale, sandstone, basalt, and obsidian. Make a list of your sample minerals and rocks and under each write as many of its characteristics as you can, such as, for example, its color, its relative hardness as determined by whether it can be easily scratched with a nail, whether it seems to be made up of crystals, and whether bubbles of gas (carbon dioxide) are given off when a drop of vinegar or other acid is placed on its surface.

Exercise on scientific method (evaluating procedures). Why are you asked in this experiment to secure at least two specimens of each mineral?

1. Iron. Iron is the most valuable of all the metals. This statement does not mean that an ounce of iron is worth more than an ounce of any other metal. For there are many metals which are worth more by the ounce than iron. But iron is the most *useful* of all metals, and, next to aluminum, is most abundant.

[1] *Metallic* (me tal'ik): containing a metal, like a metal, or being a metal.

Steel is made from cast iron. Steel is never pure iron, but contains from 1.6 per cent to 2 per cent of carbon. Part of this carbon is chemically combined with the iron and part is merely mixed with it. Sometimes the steel is alloyed with other metals. An alloy is formed by melting two or more metals together. Thus, various kinds of steels for different purposes, such as tools, automobile and airplane parts, safes, and machinery, are made by alloying the iron with small amounts of nickel, tungsten, chromium, and other metals, besides carbon.

2. Copper. Copper is probably, next to iron, the most useful of all the metals. Long before the white men came to America the Indians had found copper along the southern shores of Lake Superior. They used it chiefly for arrowheads.

Copper ores are found abundantly in many parts of Canada and of the United States, principally in the West (Fig. 237). Copper is made into many useful articles, among them electrical wires, nails and sheets for ship bottoms, window screens, and roofing. Brass, an alloy of copper and zinc, and bronze, an alloy of copper and tin, are used in making ornaments and house fittings. Brass is finding an increasing use in the manufacture of water pipes and plumbing supplies. Statues are often made of bronze.

Copper kettles were formerly much used for cooking, and to some extent they are still so used. But vinegar and the juices of acid fruits, such as berries and tomatoes, combine chemically with copper to form substances which are more or less poisonous. Iron and aluminum are therefore better materials for cooking vessels than copper.

3. Gold. Gold is the most beautiful of all the metals, but compared with iron and copper is not very useful. Pure gold is always yellow. The white gold, green gold, and red gold used in jewelry are all alloys of gold. Pure gold is too soft to be used for coins and jewelry unless it is alloyed with copper or other metals.

Gold is found in Canada, in the United States (chiefly in California, Colorado, and Nevada), and in Alaska. It is often found in the form of flakes or small lumps mixed with sand and gravel (Fig. 238). Pure gold is also frequently found in quartz veins. There are a few gold ores in which the gold is combined with other substances.

Ewing Galloway

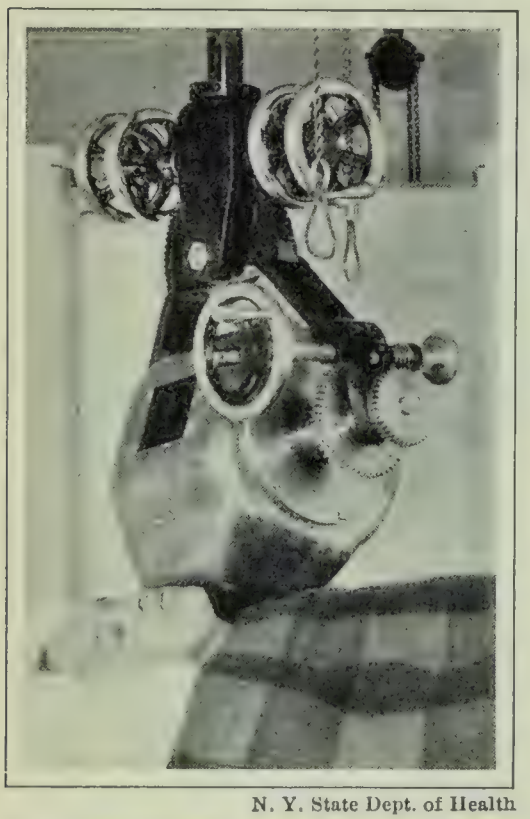
FIG. 238. Washing gold from river gravel, American River, California. This scene is near the spot where gold was first discovered in California in 1849. The gold was panned in the same way in early days. **Special Report:** How gold is extracted from ore. (Consult an encyclopedia or a chemistry textbook)

4. Mercury. Mercury is interesting because it is the only metal which is in a melted, or liquid, state at ordinary temperatures. In fact, it does not freeze (become solid) until the temperature becomes $-39°$ C. Mercury is seldom found free in nature, like gold and copper, but is usually obtained from ore in which it is combined with sulfur.

Mercury is one of the densest metals. Iron, copper, zinc, tin, and lead will all float in mercury. Mercury is used in thermometers and barometers, in mercury-vapor lamps, and in some explosives. When alloyed with other metals it has a number of uses. The backs of cheap mirrors are "silvered" with an alloy of tin and mercury, and an alloy of silver, tin, and mercury is used for fillings in teeth. Various compounds of mercury are widely used in medicine.

***5. Radium.** Radium is the most unusual of all the metals. Both radium and its compounds are constantly giving off energy in the form of light, heat, and three other kinds of rays. Radium also breaks up of itself and forms two other entirely different elements, helium and lead.

*Much experimenting is being done with radium, but few uses have yet been found for it. Its compounds, however, can be used to make luminous paint. The rays from its compounds, moreover, kill bacteria and destroy certain growths in the body. Hence radium is being widely used in medical experiments (Fig. 239).



N. Y. State Dept. of Health

FIG. 239. Using three hundred thousand dollars' worth of radium in a hospital. Special Report: The discovery of radium by Madame Curie

It takes about five hundred tons of radium ore to make one gram of radium. Because radium ore is not found in large quantities in any part of the world, and because radium is so difficult to separate from its ores, its cost is now about $70,000 per gram. At this rate a pound (if a pound could be obtained) would be worth at least $30,000,000.

6. Silver. Silver is obtained from its ores, which are mined in several of the mountain states of the West. It is used chiefly for coins, jewelry, and table silver. It is also used in silvering expensive mirrors. Its salts are valuable in photography. Silver, like gold, is too soft to be used for coins in its pure state, and hence it is alloyed with a small percentage of copper.

7. Aluminum. Aluminum is the lightest of all the common metals. Pure aluminum is never found in nature, but it is a part of clay and many rocks. Aluminum is used for many purposes: as a paint for metal surfaces and in making electrical wires, cooking vessels, parts of opera glasses and telescopes, and metal parts for boats, airships, and automobiles.

Nonmetallic minerals: 1. Chalk. Chalk is limestone. The chalk cliffs of England are great beds of the shells of exceedingly small ocean animals that lived ages ago. Much of the chalk we

use in the schoolroom is chemically the same substance as limestone, but is artificially made. Chalk makes an excellent tooth powder when it has been refined enough so that it contains no rough, hard particles.

2. Lime. Lime is obtained by heating limestone. It is employed extensively in building, where it is used in mortar, in whitewash, and in plaster.

FIG. 240. Asbestos. What sentence in the paragraph on asbestos indicates that asbestos is a poor conductor of heat? Explain

3. Clay. Clay is composed of the metal aluminum combined chemically with silicon, oxygen, and water. It is used in making tile, sewer pipe, brick, pottery, and dishes. Only pure clay free from iron compounds is used for fine pottery and china.

4. Asbestos. Asbestos (Fig. 240) is a mineral which is not affected by heat. Its fibers bend easily without breaking and have a silky luster. Some is white, some is green, and some is gray. It is widely used as a packing around steam-engine boilers and in mats for laboratory use. Fireproof paint is made by mixing ground asbestos with building paint. Fireproof shingles made of asbestos are finding an increasing use. Thread made of asbestos fibers is woven into fire-fighters' clothing, as well as lamp wicks, cooking mats, and curtains for theaters.

Crystals. Sometimes water contains dissolved minerals in great quantities, as in the water from mineral springs. When this water evaporates or is cooled, the minerals deposit in the form of crystals. Crystals always have flat sides. Rock salt is a familiar example of crystal. Crystals are also formed when certain kinds of molten rock are cooled.

Experiment 53. What are the shapes of some common crystals? Make separate solutions of salt, copper sulfate, and potassium dichromate by dissolving them in hot water. Place a narrow strip of wood over the top of each glass containing one of the solutions. Hang some

pieces of thread over the strips of wood so that the ends extend into the solutions. Put the three glasses aside where the water will slowly evaporate. Crystals will form. Are they alike in shape? in numbers of surfaces?

Self-test on Problem XX–B. (*Do not write in the book.*) **1.** Mercury is a *rock*, but is not a *mineral.*

2. A sample of a pure mineral is *seldom* like *any* other pure sample of that same mineral.

3. A sample of a certain kind of rock is *most* likely to be exactly like every other sample of the same kind of *rock.*

4. The most valuable of all metals is *gold.*

5. If the temperature on the earth were always − 40° C. or lower, *most* of the metals would be frozen.

6. A metal which is constantly giving off energy is (1) gold; (2) silver; (3) mercury; (4) radium; (5) iron; (6) platinum.

7. A lump of aluminum would weigh *more* than a lump of iron of the same size and *less* than a lump of copper of the same size.

8. A mineral from which fireproof shingles are made is *clay.*

Problem XX–C · What are the Important Classes of Rocks, and How were they Formed?

The classification of rocks. Rocks differ from each other in various ways. The particles of which they are composed are of different kinds, sizes, and shapes. Some are in layers; others are not. Some have their particles weakly cemented together, and others have them very firmly cemented. These differences are largely due to the ways in which the different rocks happened to be formed.

*Rocks are usually grouped into three classes: (1) the sedimentary rocks, (2) the igneous (fire) rocks, and (3) the metamorphic (changed) rocks.

***Sedimentary rocks.** Sedimentary rocks result from erosion thus: The pebbles, gravel, sand, mud, and the like carried by streams are deposited, in strata or layers, in the quiet waters of rivers, lakes, and oceans. During long periods of time these deposits of sediment become cemented together into strata of rock. Thus, gravel deposits are cemented together to form conglomerate; clay, to form shale; sand, to form sandstone; and the

A. M. N. H. International Newsreel

FIG. 241. *A*, a fossil of a fishlike reptile; *B*, dinosaurs. Dinosaurs lived on the earth thousands of years before there were any men. Some were larger than any animals now living, while others were as small as our present small lizards. By studying the fossil remains, scientists are able to determine how these reptiles looked and how they lived. By studying the rock layers, scientists are able to tell how long ago the reptile lived. *B* was painted after a careful study of the facts which scientists learned from studying the fossil remains of these reptiles. **Special Report:** Dinosaurs. (Consult an encyclopedia or a textbook of geology)

shells and remains of ocean animals, to form limestone. Coal may be considered to be a sedimentary rock made of the remains of ancient plants. Sedimentary rocks are always in strata or layers.

Fossils. The bones and shells of animals, and other remains of animals and plants which lived on the earth ages ago, are frequently found in great numbers in sedimentary sandstone and limestone (Fig. 241, *A*). Such remains are called fossils. Fossils have been formed in several ways. In some cases the flesh and softer parts of animals decayed before their bodies became covered with sediment. But before the bones and shells could decay they became covered and were preserved. Later the sediment was changed to rock. In other cases the bodies of plants and animals were covered with sediment, and as they decayed, mineral matter dissolved in the water was deposited in place of the animal and plant materials. The resulting fossil was called a petrifaction. Thus a petrified animal or plant has often the same form and often much the same appearance as that of the animal or plant from which it has been formed. This likeness to the living form has caused many people to believe incorrectly that the plant or animal had turned to stone.

Not all the fossils are either the bones and shells of ancient plants and animals or petrifactions found in rock and in soil deposits. Sometimes the fossil consists of the footprint of an animal or the impression of a plant in mud which later changed to shale, or the burrows of worms in ancient sea sand which later changed to sandstone.

Fossils are important for several reasons: (1) They show in what places land, lakes, rivers, and seas existed in ancient times. (2) They tell of changes in climate which occurred ages ago. (3) They give knowledge concerning the distribution of ancient animals of various kinds (Fig. 241, *B*). (4) They furnish a record of the past which enables scientists to determine much of the early history of the earth since animals and plants have lived on it.

Igneous rocks. Many kinds of rocks were formed when the substances composing them were melted by the heat of the earth's interior and later cooled. Pumice, obsidian, and granite are familiar examples. Many of these "fire rocks" form crystals as they cool. Thus, granite, which cools slowly under great pressure, is formed of crystals.

Metamorphic rocks. Metamorphic rocks are formed from both sedimentary and igneous rocks. Very high temperatures, pressures, or both, or water inside the rock, or sometimes movement of the rocks, may cause sedimentary or igneous rocks to lose their former structure and to form new and different rocks, often built of crystals. Thus, marble is sedimentary limestone changed by heat to crystalline rock. Slate is shale or sometimes mud changed by pressure, but not necessarily with great heat.

Self-test on Problem XX–C. (*Do not write in the book.*) **1.** Rock from an ancient lake-bed is likely to be *igneous* rock.

2. *Few* fossils are found in igneous rock.

3. State four values derived from a study of fossils.

4. The finding of beds of rock containing sea shells on the top of a hill indicates that (1) the land which is now the hilltop was once under a river; (2) the region is volcanic; (3) erosion has taken place rapidly; (4) the hilltop was once under the ocean; (5) the hilltop is composed of metamorphic rock.

5. Metamorphic rocks are *constructed from* igneous or sedimentary rocks.

FIG. 242. Cliff dwelling at Mesa Verde National Park, Colorado. Stone dwellings like these were built in the mouths of caves high up in the cliffs by a race of people who lived in the Southwest and disappeared before the white men came to America. This palace, the largest of all the ruins found, has about two hundred rooms. The stones were cut by hand and are held together in the walls by adobe mortar. Do you infer that weathering and erosion here are relatively slow or relatively rapid?

Problem XX–D · What are the Characteristics of Common Building Materials Obtained from the Earth?

The building stones. The earliest stone houses were caves. Primitive man had no implements with which to hollow out the rock. Therefore he occupied such natural caves as he was able to find. Many thousands of years passed before men learned to cut stones for buildings (Fig. 242). The wonderful buildings that still remain from the times of ancient Greece, Rome, and Egypt were built of blocks of cut stone. In modern times, however, concrete has almost entirely taken the place of stone blocks for buildings. Building stone now finds comparatively little use except for facing steel and concrete structures and for especially beautiful buildings, such as cathedrals.

*When men began to learn how to use stone for buildings, they experimented with various kinds. Some kinds of stone proved unsuitable because they weathered too rapidly, because they would

crush under great weights, or for other reasons. At present only five natural stones find much use in buildings. These are limestone, marble, sandstone, granite, and slate. Limestone and sandstone are sedimentary, granite is igneous, and both marble and slate are metamorphic. Slate is used for the roofs of buildings but not for the walls, as are the other four.

Georgia Marble Co.

FIG. 243. Hoisting a great block of marble from a quarry. **Exercise on Scientific Method (Making Inferences):** Was this part of the country ever under water? Explain. Can you infer any other facts concerning this region?

Limestone. Limestone is a mineral formed from the shells of animals that lived ages ago in the ocean. These shells collected in strata which slowly hardened into limestone. Limestone is found in various parts of the United States. The finest deposits are in the Middle West and in Kentucky. Most of it is used locally, but the finest limestone finds a ready market in distant places. Limestone is white, gray, green, brown, and other colors. Besides its use for buildings, it is used in making fertilizers[1] and glass and in building railroads and highways. It is also used in making cement and lime and in smelting iron ores.

Marble. Marble is limestone which has been changed by heat and pressure to a crystalline rock. Marble is white, gray, black, and various shades of pink, red, brown, yellow, and green. The pure-white marble is used for monuments and statues,

[1] *Fertilize* (fer'ti lize): to make fertile. *Fertilizer* (fer'ti li zer): that which fertilizes; usually a substance that aids the growth of plants.

but it tends to weather easily and become dark. Most of the marble comes from Vermont, though valuable deposits are also found in Tennessee, Georgia, Arizona, Colorado, and California (Fig. 243).

Sandstone. Sandstone is less hard and is more easily weathered than limestone. It is widely distributed through the United States, some of the best being in the states of New York and Ohio. It is found in many shades. Some kinds are much harder and hence weather more slowly than others.

Granite. Granite weathers and erodes less rapidly than any other building stone. It is found in many colors. It occurs at or near the surface of the ground in New England. It also forms the core of many mountains in the West. It is widely used in buildings and monuments.

***Cement.** Cement is made of limestone and clay, heated and powdered. When it is mixed with water it hardens into rock. Concrete is made by mixing sand, cement, crushed stone, and water. Reinforced concrete is concrete made stronger by running rods of iron or steel through it when it is being poured.

Cement is mixed with sand in making stucco, which is used in covering buildings.

Glass. Have you ever thought how hard it would be for us to get along without glass? What should we do without glass jars, bottles, and dishes? Yet in the days of Egypt only the rulers and the wealthiest people could afford to own even a few crude bottles. How would it seem to have no panes in our windows? Yet only a few hundred years ago there were no glass windows.

*Glass may be considered one of the treasures from the earth's storehouse, because all the substances of which it is made come from within the earth; in fact, certain igneous rocks are very much like glass, one (obsidian) being called volcanic glass. All glass is made by heating sand to a high temperature with certain compounds of some of the metals. Thus, sand heated with compounds of sodium and calcium produces window glass and bottle glass. Sand heated with compounds of potassium, lead, and aluminum produces other kinds of glass. The sand and the metal compounds are heated in a furnace until they melt, forming a thick liquid. This half-liquid glass is blown against the inside walls of

molds, forming bottles, lamp shades, and similar objects. In the more modern factories compressed air is used in blowing the glass, but in some of the plants men blow the glass even yet.

FIG. 244. Testing laminated glass. The steel ball now in the man's hand is held by the electromagnet at the top and is released when the current through the magnet is shut off. The ball falls upon the plate of glass placed in the screened box. Why is this kind of test a scientific one?

Safety glass. A large percentage of all injuries received in automobile accidents is caused by the shattering of the glass and the consequent cutting of the people by the broken pieces. To decrease the number of such injuries most automobile manufacturers are equipping their automobiles with "laminated" safety glass (Fig. 244). This glass consists of three layers. The two outer layers are made of plate or sheet glass, between which is a layer of celluloid or a similar-appearing substance which will better resist light and heat. The three layers are laid carefully together and are then united by means of heat and pressure. The edges are then sealed to protect the inside layer from the weather.

Self-test on Problem XX–D. (*Do not write in the book.*) 1. The most valuable artificial rock used in the construction of great buildings, dams, and the like is (1) limestone; (2) granite; (3) asbestos; (4) concrete; (5) slate; (6) clay.

2. Name the five natural stones which find the chief use in building construction.

3. Limestone is an *igneous* rock.

4. Marble is a *sedimentary* rock.

5. Granite is an *igneous* rock.

6. All glass contains (1) clay; (2) aluminum; (3) sand; (4) soil; (5) lead.

Self-test on Scientific Principles. What facts can you quote from this chapter which support the principle "The present is the key to the past"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Which geyser should you expect to spout more often, one with a short pipe or one with a long pipe, providing conditions otherwise were just alike? Why? Which should you expect to spout higher? Why?

2. Can you think of two reasons why the ground around the openings of geysers is coated with deposits of mineral matter?

3. How many uses of iron and steel can you name in three minutes?

4. How many uses of concrete and reinforced concrete can you think of in three minutes?

Project. To make concrete and reinforced concrete and to see which is stronger. Stir together five parts of dry coarse sand and one part of dry cement. When they are thoroughly mixed add water, stirring meanwhile, until you have a thick paste. This is concrete. Secure two boxes of the same size. Fill one with the concrete. Put a layer of concrete in the other; then put a piece of wire screen on top of this layer. Add another layer of concrete and another piece of screen on top of this, and so on until the box is filled with several layers of concrete with wire screen between them. Keep the concrete in both boxes moist for several days; then allow it to harden for two weeks. Remove the boxes and, with a heavy hammer or sledge, break the concrete blocks. Which is harder to break to pieces?

Special Reports. 1. What is petrified wood, and how is it formed?

2. Describe the Painted Desert in Arizona. How was it formed?

3. Locate on an outline map of the United States and Canada the most important coal deposits.

4. Diagram a blast furnace and explain its action.

5. How many uses of aluminum can you find in your home and elsewhere?

6. In what parts of the United States and Canada are fine china and pottery made? Describe the processes of making them.

7. How is gold ore mined? Describe the processes by which the gold is recovered from the ore.

Exercises on Scientific Attitudes. 1. After the following problem you will find five statements. See whether you can pick out the one which a carefully trained scientist would consider best. Then see whether you can find which of the scientific attitudes (pp. 12 and 13) is illustrated by the problem and the best statement.

Crater Lake, in Crater Lake National Park, Oregon, occupies the crater of a great volcano (Mount Mazama), which has been inactive for many centuries. This lake is said by some people to be so deep as to have no bottom.

a. No doubt the statement is true.

b. The statement could be true because there are other lakes that some people think are so deep that they have no bottoms.

c. I will believe it has a bottom when I see scientific proof that it has.

d. The statement is absurd.

e. The statement is probably false.

2. John found in a newspaper the statement that Mount Everest is 29,456 feet high. He wondered whether the statement were true. Which of these comments and suggestions made by his classmates would a scientist be likely to consider best? Can you quote one of the scientific attitudes to support your choice?

a. Look up the height of Mount Everest in an atlas.

b. It must be true if the paper says so.

c. What difference does it make whether the statement is true or not?

d. Ask the science teacher.

e. There's no way of knowing how high Mount Everest is because nobody has ever been to the top of it.

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TALBOT, F. A. A. All about Treasures of the Earth. Funk & Wagnalls Company, New York.

VERRILL, A. H. The Boy Collector's Handbook. Robert M. McBride & Company, New York.

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UNIT VIII · *Magnetic and Electrical Energy and their Uses*

PROBLEMS DISCUSSED IN THIS UNIT

Lightning and the accompanying thunder are prominent in the religious beliefs of many ancient peoples. Thus Jupiter, king of the Greek gods, was believed to throw thunderbolts at his enemies. Certain Indian tribes thought that thunder was caused by the flapping of the wings of a huge but unseen thunderbird. The earliest scientific knowledge of electricity, however, is credited to Thales, a Greek (640 B.C.–546 B.C.), who knew that amber could be charged with electricity and would then pick up bits of straw or pith.

A little knowledge of magnetism was possessed by the ancients several centuries before Christ. There is the fable of Magnes, a Cretan shepherd, who discovered a wonderful magnetic stone, of the kind which we now know as lodestone. Then there is a fable in the Arabian Nights which describes a magnetic mountain powerful enough to pull nails out of distant ships. Other fables of other centuries describe the impossible feat of suspending in the air, by means of magnets or lodestone in the roofs, the iron statue of an Alexandrian queen, an iron statue of the horse of Bellerophon weighing five thousand pounds, and also the iron coffin of Mohammed.

From such unscientific beginnings we have reached the stage of knowledge where magnetic and electrical energy are among the most important factors in civilization. These problems are here discussed:

What are some important characteristics of magnetism?
What are some important characteristics of static electricity?
What are some important characteristics of electrical currents?
How is chemical energy changed to electrical energy in electrical cells?
What is the relation between magnetism and electricity?
How can electrical energy be used in electrolysis?
How is electrical energy brought into the home and used in it?

Chapter XXI · The Energy of Magnetism and Static Electricity

Questions this Chapter Answers

What are magnets and what are their properties?
What is the nature of magnetism?
What are the principles of magnetic attraction and repulsion?
How are magnets made by induction?
Does the earth possess magnetism?
How are electric charges produced?
What are the principles of electrical attraction and repulsion?
What is electricity?
What is lightning?
How can buildings be protected from lightning?
How may one reduce the danger of being struck by lightning?

Problem XXI-A · What are Some Important Characteristics of Magnetism?

Early ideas about magnetism. As has been stated, people have known for more than two thousand years that there were certain stones which were magnetic and hence would attract iron. Some of the ancients knew also that pieces of steel could be magnetized[1] by rubbing them against these magnetic stones, or natural magnets. Such natural magnets are of lodestone, which is now known to be one of the compounds of oxygen and iron.

Progress in the study of magnets. No practical use was made of the knowledge of magnets or of magnetism until someone discovered that when a magnet is allowed to float freely it will turn until it points north and south. This discovery led to the invention of the compass. The compass was probably first invented by the Chinese, and was introduced into Europe about the twelfth century. There is, however, no proof that the Chinese understood magnetism before 121 A.D., though Chinese legends centuries older mention "south-pointing chariots" and "south-pointing ships" which may have been compasses. Before the

[1] *Magnetize* (mag'net ize): to make into a magnet.

invention of the compass sailors steered their boats by objects on the shore and by the stars. Consequently they feared to start on long ocean journeys. The use of the compass made possible the voyages of discovery by Columbus and others. These voyages opened new lands and also established the fact that the earth is spherical.[1]

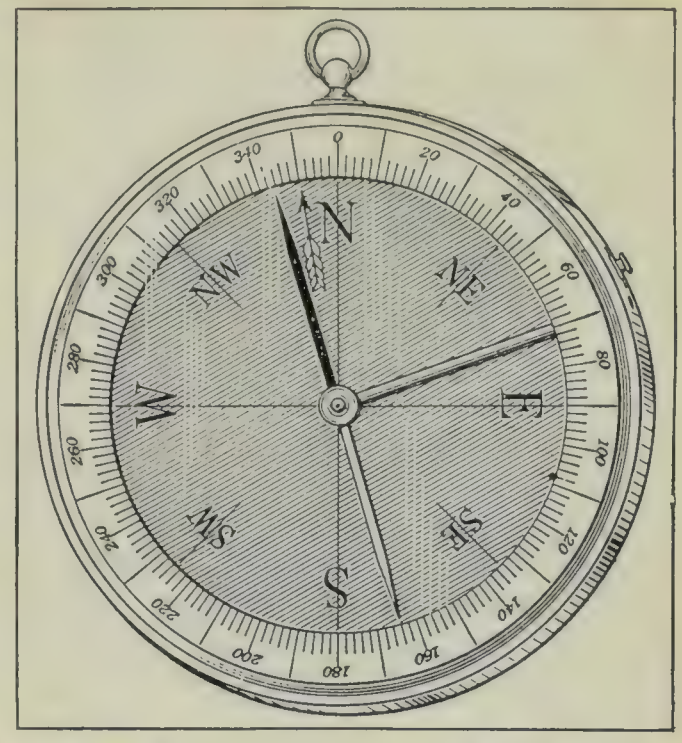

FIG. 245. A magnetic compass. Why is the case made of brass instead of iron? Why is the compass considered one of the greatest inventions in human history?

*Except for the compass, there was little or no practical use made of magnetism until the last century. Two important facts were then discovered: (1) that an electrical current is surrounded by magnetism and (2) that magnetism can be made to produce an electrical current. These discoveries made possible the invention of most of the modern electrical machines which are familiar in our daily lives.

***Magnets.** You are doubtless familiar with the U-shaped magnets which are used with many magnetic toys and games. Sometimes the magnet is not bent into the shape of the letter U, but is straight. U-shaped and bar magnets are nearly always made of hard steel, because hard steel can be strongly and permanently magnetized. Iron and steel and certain alloys of iron, moreover, are the only substances that can be strongly attracted by a magnet. Iron or steel is magnetized by stroking it with one end of a magnet or by means of electric currents. A compass is only a small bar magnet which is free to turn around on a point (Fig. 245). The end of the compass which points toward the north

[1] *Spherical* (sfer'i kl): like a sphere.

is called the north, north-seeking, or *N* pole. The end which points toward the south is called the south, south-seeking, or *S* pole.

The first magnetic compasses were probably steel needles which had been magnetized by rubbing them with lodestone. They were then probably floated upon a piece of wood or inside a reed in a bowl of water. (See project, p. 381.)

Magnetism. We can now learn in a few minutes some of the interesting facts learned little by little by scientists through centuries of patient experimenting.

Experiment 54. Do magnetic poles attract or repel[1] other magnetic poles? Bring the *N* pole of a magnet within a few inches of the *N* pole of a compass needle. What happens? Now hold the *S* pole of the magnet near each pole of the needle in the same way. Repeat. Can you fill the blanks in the following sentence so that it will make a true statement (*Do not write in the book*)?

A north pole of a magnet attracts (that is, pulls toward it) the _ _ (?) _ _ pole of another magnet, and the south pole of a magnet attracts the _ _ (?) _ _ pole of another magnet.

Is the following statement true? If not, can you make it true by changing one or both italicized words?

*The same kind of magnetic poles *attract* each other, and opposite kinds of magnetic poles *repel* each other.

Experiment 55. We have learned that a magnet will attract pieces of unmagnetized iron or steel. Will a piece of unmagnetized iron or steel attract a magnet? Find out by holding an unmagnetized nail near each pole of a compass needle in turn. Select the ending of the following sentence which makes a true statement with the first part of the sentence:

When unmagnetized iron is brought near a magnet,
(1) the unmagnetized iron attracts both poles of the magnet.
(2) the unmagnetized iron attracts neither pole of the magnet.
(3) the unmagnetized iron attracts the north pole but not the south pole.
(4) the unmagnetized iron attracts the south pole but not the north pole.
(5) the unmagnetized iron repels both poles of the magnet.

Experiment 56. Does a magnet always have only two poles, an *N* pole and an *S* pole, or may it have more than one of each kind of pole? Present a piece of lodestone to the *N* pole of a magnetic compass. Turn the lodestone round so that different points on its surface are near the *N* pole of the compass. What do you conclude?

[1] *Repel* (re pel'): to push something away or force something back.

The magnetic field of force surrounding a magnet. We have learned that the magnetic energy extends *in all directions* from the magnet through the space round it. The space round a magnet where the magnet can exert a force and do work upon iron or steel is called the magnetic field.

Experiment 57. What is the magnetic field surrounding a magnet like? Place a magnet on the table between two books or magazines a little thicker than the magnet. Place a sheet of paper on the books so that its center is over the magnet. Sprinkle iron filings evenly over the paper. Tap the paper gently until you get a clear pattern of the filings (Fig. 246).

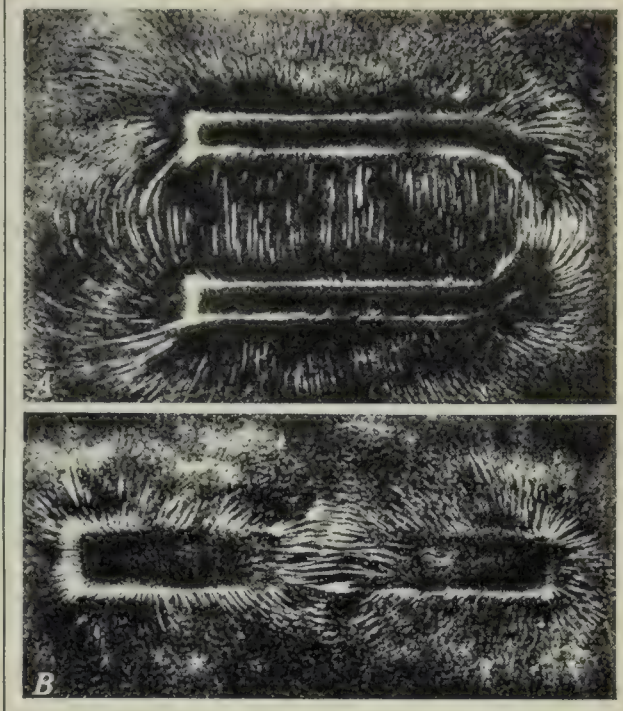

FIG. 246. Magnetic fields around a U-shaped magnet (*A*) and a bar magnet (*B*). **Project:** To make figures like these. Sprinkle iron filings on blueprint paper placed above a magnet as in Experiment 57. Expose the paper with the filings on it to the sunlight for two or three minutes. Then put the paper in water to fix the print

The lines located by the iron filings in the field of the magnet are called magnetic lines of force. These lines of force go through the air in all directions from the *N* pole of the magnet to the *S* pole.

Induced magnetism. *Experiment 58.* Can iron or steel be made a magnet by induction, that is, by merely bringing it near a magnet? Dip one pole of a magnet into a pile of very small nails or iron filings (Fig. 247, *A*). Do the nails or the filings that touch the magnet become magnetized? Do the nails or the filings that do not *directly* touch it become magnetized? How do you know in each case? Now, without jarring the other nails or the filings, very carefully pull away from the magnet some of the nails or the filings that touch it. Do they all keep their magnetism when they are separated from the magnet?

Hold a magnet in one hand, and with the other hold a nail so that its head is very near the magnet but not touching it (Fig. 247, *B*). See whether the point of the nail will attract small nails. Take the magnet away. Is the magnetism of the large nail made greater or less when the magnet is removed?

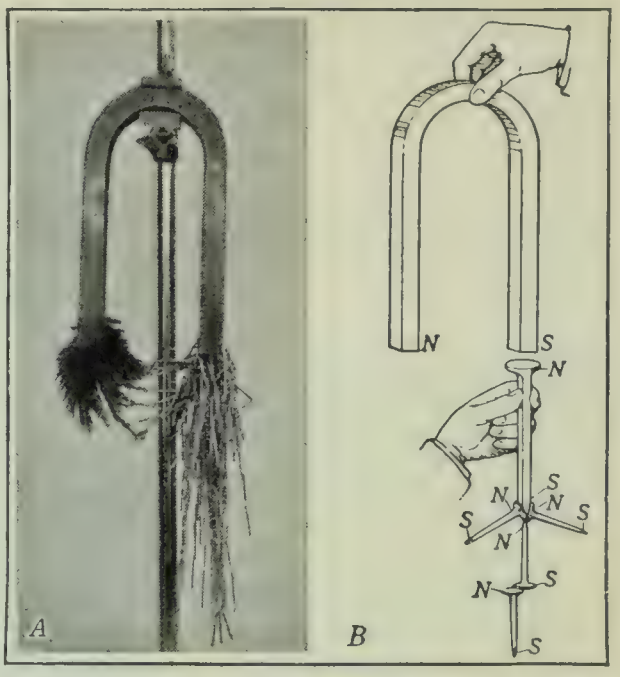

Fig. 247. Magnetic induction. Why do the filings and the nails join, and why do some of the lines of nails extend out to touch the iron stand? Can you explain why each nail in *B* has at the end nearest the inducing magnet a pole *opposite* in kind to the pole of the permanent magnet, and at the end farthest from the permanent magnet a pole of the *same* kind as the pole of the permanent magnet? Can you explain why the little nails spread apart instead of hanging side by side from the ends of the big nail? Does the same reason account for the fact that iron filings stand out from the end of a magnet? Explain

The magnetized iron or steel has induced magnetism while the magnet is near it. The process of magnetizing a piece of iron or steel by merely bringing it near a magnet is called magnetic induction. Thus the large nail became magnetized by induction, and while it was magnetized it magnetized the small nails by induction. Magnetism is more easily induced into soft iron than into hard steel. But in the case of soft iron, as soon as the inducing magnet is taken away, the induced magnet loses nearly all its magnetism. Thus we say that induced magnetism is temporary or permanent according to whether the material of which the magnet is made is soft iron or hard steel.

***The earth's magnetism.** The earth is considered to be a magnet because in most parts of it the compass needle takes a general north-and-south position. The magnetic poles, however, are not located at the geographical[1] north and south poles. For

[1] *Geographical* (je o graf'i kl) or *geographic* (je o graf'ik): having to do with geography.

this reason the compass does not point *exactly* north and south in most places on the earth. In our eastern states the *N* pole of the needle points slightly northwest; in the western states, slightly northeast (Fig. 248).

FIG. 248. A compass at any point on the line points true north. Which should you expect to point more directly north, a compass needle in Florida or one in Utah?

Self-test on Problem XXI–A. (*Do not write in the book.*) 1. The best substance of which to make a bar magnet is (1) copper; (2) iron; (3) tin; (4) sealing wax; (5) lodestone.

2. A magnet will pick up pieces of (1) copper; (2) tin; (3) aluminum; (4) iron; (5) paper.

3. *Both ends* of a compass needle will be attracted if the compass is placed near one of the poles of a U-shaped magnet or of a bar magnet.

4. North-magnetic poles *attract* south-magnetic poles and *repel* other north-magnetic poles.

5. Magnetism is a form of *power*.

6. A piece of soft iron will *usually* become magnetized when it is brought near a strong magnet.

7. At the geographical north pole the *N* pole of a compass would point (1) to Alaska; (2) to Canada; (3) to Greenland; (4) to Norway; (5) to Russia; (6) to Siberia; (7) straight up; (8) in no particular direction.

8. Iron and steel are more easily *magnified* than other metals.

Problem XXI–B · What are Some Important Characteristics of Static Electricity?

Electricity produced by friction. If you have ever stroked a cat's fur in dry, cold weather, you have observed a crackling sound as your hand moved along the cat's back. If you did this when the room was dark, you could see sparks on the fur. If you rub a fountain pen on wool clothing, or if you pass a hard-rubber

comb through your hair, the pen or the comb will afterwards pick up small bits of paper. (Try this.) In these cases the cat's fur, the fountain pen, and the comb have become electrified[1]; that is, some of the mechanical energy of the rubbing has been transformed into electrical energy.

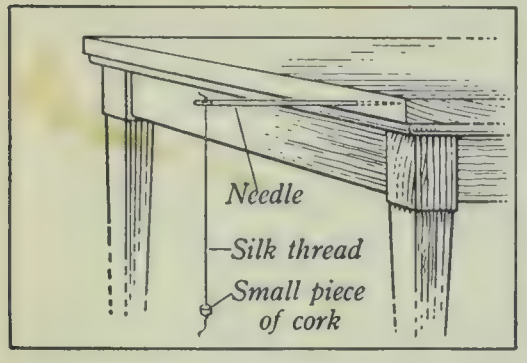

FIG. 249. Will a fountain pen which has just been rubbed on woolen cloth pick up chalk dust? hairs?

*Electrical energy of this kind is called static, or frictional, electricity. It is usually produced by the friction caused by rubbing one object upon another. People sometimes confuse static electricity with magnetism, though these two kinds of energy are different. The magnets we have studied are made of iron or steel and are able to attract only iron and steel. But many familiar substances can be electrified, and when they are electrified they will attract small bits of almost any substance.

Electrical charges. ***Experiment 59.*** Can static electricity be produced on hard rubber and woolen cloth by rubbing them together? Thread a sewing needle with dry silk thread. Pass the needle through a very small bit of cork. Push the cork to the bottom of the thread as you would string a bead. Suspend the cork as shown in Fig. 249. Rub a fountain pen vigorously with a piece of woolen cloth. Quickly bring first the pen, then the cloth, near the cork. Do not touch the cork. Is the cork attracted by both the pen and the cloth? Make a complete sentence answering the question asked at the beginning of this experiment.

*There are two kinds of static electricity: plus, or positive, and minus, or negative. In this experiment, minus electricity was produced on the fountain pen and positive electricity was produced in equal amount on the woolen cloth.

Experiment 60. Can static electricity be produced on glass by rubbing it with silk? Tear a piece of newspaper into very small bits. Scatter some of these on the table. Place two books, about half an inch thick, so that they will hold a glass plate between them, just above the bits

[1] *Electrify* (e lek'tri fi): to charge with electricity or electrical energy.

of paper. Rub the glass plate *vigorously* with a silk cloth. What happens? Explain. How would you determine whether the silk cloth had a charge after it was rubbed on the glass plate? Does the silk have a charge? If the glass has a plus charge, what kind of charge should you expect the silk to have?

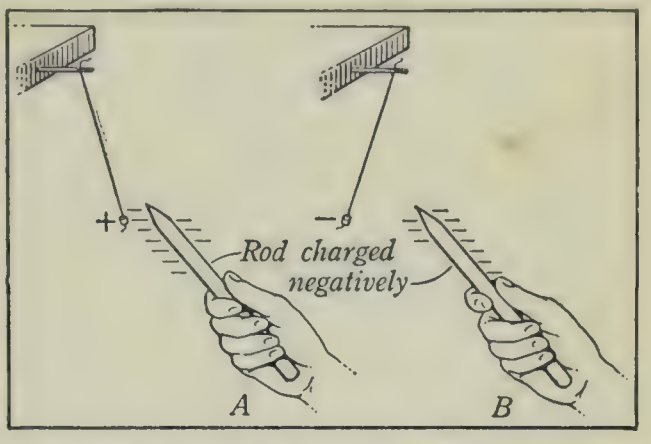

FIG. 250. Can you explain these diagrams?

Experiment 61. How do plus and minus charges act toward each other? Electrify the fountain pen and the wool cloth as before. Allow the cork (Fig. 250) to touch the fountain pen in several places. Now bring the minus-charged pen near the minus-charged cork. Do the two minus charges attract each other or repel each other? Again rub the pen vigorously on the cloth, and charge the cork by allowing it to touch the pen. Then quickly bring the plus-charged cloth near the minus-charged cork. Do the two unlike charges attract each other or repel each other?

Is the following statement true or false? If it is false, can you make it true by changing one or both italicized words?

*Electric charges of the same kind *repel* each other and electric charges of opposite kinds *attract* each other.

Is this statement for electrical attraction and repulsion (that is, attracting and repelling) similar to the law of attraction and repulsion of magnetic poles (see page 370)?

What is electricity? It has long been known that electricity is a form of energy. Recently scientists have learned much concerning the real nature of electricity. You will remember the statement made on page 112, that all matter is composed of molecules, and that these molecules are particles so small that a thousand together could scarcely be seen with the strongest microscope. If a drop of water were magnified until it was the size of the earth, the molecules that made up the drop would then be about the size of golf balls. Each kind of molecule contains a certain number of atoms. The same kind of molecule always contains the same number of atoms. These atoms are very much smaller than

the molecules. In the middle of each atom is a nucleus.[1] This nucleus always contains one or more positive electrical charges, or protons, and generally a smaller number of negative electrical charges, called electrons. In every atom there are also one or more negative charges, or electrons, outside the nucleus. Thus the hydrogen atom has a nucleus consisting of a single proton, and outside this nucleus is a single electron. Other atoms have more than one proton in the nucleus and more than one electron outside the nucleus. The total number of electrons inside and outside the nucleus, however, always equals the number of protons inside the nucleus. A proton weighs about 1845 times as much as an electron.

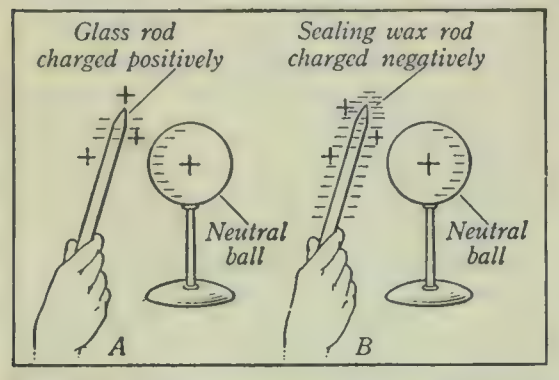

FIG. 251. Can you explain these figures?

How electrons act. When the total of the negative charge of the electrons in an atom is exactly equal to the positive charge in the nucleus of the atom, the atom is then neutral; that is, it is neither positive nor negative. When an atom loses some of its electrons, the total of the negative charge left in the atom is less than the positive charge of the nucleus. Therefore the atom becomes positive. In the same way, when an atom gets extra electrons, the total negative charge is greater than the positive charge of the nucleus, and the atom is then negative. To illustrate: when the fountain pen was rubbed on the woolen cloth, some of the electrons were rubbed off the atoms of the woolen cloth onto the hard rubber. The result was that the rubber had gained extra negative charges, which made it negative, and the woolen cloth had lost electrons and was therefore positive.

A body which lacks electrons and hence is positively charged attracts bodies which have extra negative electrons and hence are negatively charged (Fig. 251, *A*), and repels other positive bodies. In the same way, a body which has extra electrons and is therefore negatively charged repels other negative bodies which are near it and attracts positive bodies. Whenever a negative body touches

[1] *Nucleus* (nu'kle us): the denser central portion of a body.

a positively charged body, the negative body gives up its extra electrons to the positive body. The jumping of great numbers of electrons between bodies having opposite charges of static electricity causes a spark such as one sees when stroking a cat's fur.

Whenever a positively charged body comes near a neutral body (that is, one with equal positive and total negative charges) which is a good conductor of electricity, the negative electrons are attracted to the side nearest to the positively charged body, leaving the opposite side of the neutral body positive. If a negatively charged body comes near such a neutral body, the electrons rush to the side farthest from the negatively charged body, leaving the side nearest to the negatively charged body positive. Can you state a reason to account for these last two statements?

Self-test on Problem XXI–B. (*Do not write in the book.*) **1.** When a hard-rubber pen is rubbed on woolen cloth, the rubber becomes *magnetized.*

2. Like charges *attract* each other and unlike charges *attract* each other.

3. When you stroke a cat's fur, *magnetic* energy is transformed to *electrical* energy.

4. When a body attracts small bits of paper, then we know that the body is *magnetized.*

5. When a body loses some of its electrons, the body is *negatively* charged.

6. If a negatively charged body is made to touch a positively charged body, electrons pass from the *second* body to the *first.*

7. A body with extra electrons will be *attracted* by another body having extra electrons.

Problem XXI–C · How does a Knowledge of the Nature of Lightning Enable us to Protect ourselves against It?

***The nature of lightning.** Lightning is static electricity. It jumps from one body to another as do the sparks of static electricity which you produce when you rub a cat's fur. Electrical charges are produced in the clouds (Fig. 252) probably by the friction of the wind on the cloud and by the evaporation and condensation of water vapor. If these charges become great enough, the lightning may jump between two clouds, or between a cloud

and the ground, just as sparks jump between one's hand and a cat's fur. When it strikes, lightning usually hits some object, such as a tree or a tall building, which is higher than the surrounding objects. Lightning may strike the same tall tree or the same tall building again and again.

FIG. 252. What kinds of energy are transformed into the electrical energy of lightning?

Lightning rods. Lightning rods are a valuable means of protection from lightning, in the country especially. In the city the soil pipes from the drains serve the purpose of lightning rods. To be effective, a lightning rod must be grounded; that is, buried deeply enough so that its end is always surrounded by moist earth, because moist earth is a good conductor of electricity and dry earth is not. This statement means that electrons pass easily through moist earth but have difficulty in passing through dry earth.

If lightning should strike a house or a barn having lightning rods, the lightning would probably run down the rods and into the ground without harming the building. The chief function of lightning rods, however, is to protect buildings by preventing the lightning from jumping. Thus when a cloud charged with positive electricity approaches a building equipped with lightning rods (Fig. 253), the rods become charged negatively. The reason is that the positively charged cloud attracts extra electrons from the ground to the top of the rod. The molecules of air near the point of the lightning rod then take on extra electrons from the negatively charged rod. The air molecules thus become negatively charged. These charged molecules are then attracted to the positively charged cloud, which takes away from them the extra

FIG. 253. The lightning rods quietly neutralize the cloud. Explain. Can you explain how the lightning rods would discharge a negative cloud?

electrons they received from the lightning rod. The result is that the cloud is quietly neutralized, or made neutral, so that the lightning flashes from it are smaller; or, if there are enough lightning rods in the neighborhood and other objects such as tall trees, the charge on the cloud is neutralized and the lightning is entirely prevented.

***Protection from lightning.** Although most people fear the lightning, there is really very little danger of being struck by it. It has recently been estimated that the chances that a person will be struck by lightning in his home are only one in many millions. However, it is prudent during a thunderstorm to keep away from all grounded conductors, such as radiators, heating pipes, water pipes, the radio, the telephone, and lighting fixtures. Also it is wise not to stand between such good conductors as the stove and the sink or near open windows or close to a chimney. When you are out of doors during a thunderstorm, moreover, do not stand under a tree that is not near other trees and do not stand where your head is higher than other objects about you.

Self-test on Problem XXI–C. (*Do not write in the book.*) 1. Lightning is electrical *power*.

2. One stands less chance of being hit by lightning if one's head is *above* surrounding objects.

3. Lightning rods are of value *chiefly* if their lower ends are in moist earth.

4. Lightning consists of *protons* in motion.

5. During a thunderstorm it is *less* dangerous to stand in a grove than under a single tree.

6. In general, city houses are *more* liable to be struck by lightning than country houses.

Self-test on Organization of Facts. Compare the phenomena of magnetism with those of static electricity. In one column write all the respects in which they are similar and in the other write all the respects in which they are different. (See "To the Student," p. xvi.)

Self-test on Scientific Principles. How would you explain and illustrate these two important principles to a boy or a girl of your own age who had never studied science?

Magnetic poles of the same kind repel each other, and magnetic poles of opposite kinds attract each other.

Electric charges of the same kind repel each other, and electric charges of opposite kinds attract each other.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. How could sailors steer their boats by the stars?

2. If you brought a knitting needle near a compass, could you be sure the needle was a magnet if it attracted the compass needle? Explain.

Exercises on Scientific Method (Inventing Experiments). 1. How would you proceed to find out whether or not a tin can was really an iron can coated with tin? Perform your experiment.

2. How would you proceed to find out whether a magnet always has only two poles or whether it may have only one or several? Can you plan more than one way of finding the answer to this problem? Old magnets which have not been magnetized in a long time and pieces of lodestone are good materials to use in this experiment.

3. If you were given two bar magnets, how would you proceed to find out which was the stronger?

4. If you were given two bar magnets on neither of which the poles were marked, how would you proceed to find out the *N* pole and the *S* pole of each?

Projects. 1. How can a magnetic compass be made? Make a magnet out of an ordinary steel sewing needle by rubbing the needle from one end to the other with one end of a magnet. Always be sure to rub from the same end of the needle and to rub in the same direction with the same end of the magnet. Stick the needle (which is now itself a bar magnet) through a small cork so that when the cork is put into water the needle will float above the surface of the water (Fig. 254). Does the needle turn round until it points in any certain direction? Turn the needle in different directions to see whether it will turn of itself so as to point always in a certain direction. Does the floating needle act like a compass?

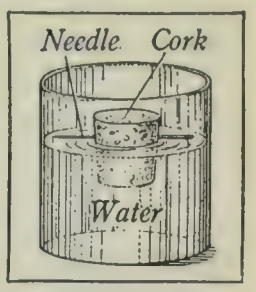

FIG. 254. A home-made compass. Do not bring near this compass magnets or other objects made of iron or steel. Explain

2. How can a magnetic compass be made? Make a magnet out of an ordinary knitting needle in the way described in the preceding project. Tie one end of a string or a thread around the knitting needle as near the middle as you can so that the needle will lie about level when it is suspended. Suspend the needle by the other end of the string or thread. Does the needle turn so that it points in any certain direction? Turn the needle in different directions to see whether it will turn so as to point always in the same direction. Does the suspended needle act like a compass?

Special Reports. 1. What is the story of Benjamin Franklin's securing electric charges from the clouds by means of a kite? Did Franklin run any risk in performing this experiment? Explain.

2. Describe the type of compass that is used on ocean vessels.

3. How do sailors determine the positions of their ships on the ocean? (This topic will probably be found in an encyclopedia under the heading "Navigation.")

4. What type of compass is used in airplanes?

Question for Debate. *Resolved*, That the invention of the magnetic compass was more important and valuable than the invention of the barometer.

Books for Reference

BURNS, E. E. The Story of Great Inventions. Harper & Brothers, New York.
MEISTER, MORRIS. Magnetism and Electricity. Charles Scribner's Sons, New York.

Science and Progress

WHAT would the boys and girls of a hundred years ago have thought and how would they have acted if they could suddenly have jumped ahead a century to explore *our* environment! Think how magical it would seem to them to see streetcars speeding by with no oxen or horses to pull them! Wouldn't they enjoy pushing the button on the wall and flooding the

FIG. 255. Eighteen forty looks at nineteen forty

room with light more brilliant than any they had dreamed of! Wouldn't their eyes grow big with wonder and delight at the sight of the electric signs so familiar to us! Wouldn't they marvel over a modern kitchen with its electrical range and other electrical appliances!

They would ask you breathlessly how such wonderful things could be possible. You would tell them, in a matter-of-fact tone: "Why, that's easy. These things are done by electricity—electric currents, you know." It would all seem like magic to them.

How you would enjoy their puzzled expressions at your explanation! "Electric currents? What are they? We never heard of them." They would know of no books which could tell them anything about electric currents. Not even the greatest scientists of their day could tell them as much as you will know when you have finished the study of this unit.

Special Reports. 1. What electrical inventions were known to Benjamin Franklin?

2. What electrical inventions were in use a century ago? (Consult books on the history of science.)

Chapter XXII · Getting Acquainted with Electrical Currents

Questions this Chapter Answers

What are electrical conductors and insulators?
What is the relation between electrical pressure and electrical current?
What are the units of electricity?
What are electric cells, and how do they change chemical energy into electrical energy?
What are series connections and parallel connections?
What are electromagnets?
How are electromagnets used in the construction and the operation of electrical generators or dynamos?
What kinds of energy can be transformed into electrical energy by means of generators?
How are electromagnets used in the construction and the operation of motors?

Problem XXII–A · What are Some Important Characteristics of Electrical Currents?

Knowledge of electricity a common need. Wherever you go or whatever you do in almost any part of the world, you need to make some direct or indirect use of electrical currents. Even Rear Admiral Byrd in his long expeditions into the region of the south pole made many practical uses of electricity. Because electricity is so useful and so common, everybody in these times needs to know something about the nature and sources of electrical currents (Fig. 255). Some of the most important electrical facts and principles are presented in this chapter.

Conductors and insulators. There are certain substances, such as the metals, which have many free electrons; that is, electrons readily escape from the atoms and enter other atoms. Electrons are able to pass through such substances readily. There are other substances, such as hard rubber and glass, which have relatively few free electrons, and electrons will scarcely pass at all through such substances. Any substance through which electrons pass in relatively great numbers and without difficulty is called a con-

ductor. Any substance through which electrons pass in relatively small numbers and with difficulty is called a nonconductor or insulator.

Electrical pressure and electrical current. Whenever a body gains or loses electrons a sort of "electrical pressure" is produced in the body. The greater the extra supply of electrons or the greater the lack of electrons the greater is this pressure. You will recall that a minus-charged body is one having extra electrons, and that a plus-charged body is one lacking electrons. When a plus-charged body is connected by a conductor to a minus-charged body, the difference in electrical pressure between the two bodies forces a stream of electrons through the conductor from the minus body to the plus body. The greater the difference in pressure, the greater is the stream of electrons through the conductor. Such a stream of electrons is an electrical current.

Units of electricity. "Electrical pressure," or the electrical energy which forces current through a conductor, is called electromotive force or E.M.F. or voltage. The unit of E.M.F. is the volt. The unit of electrical current is the ampere. Thus volts of electromotive force send amperes of electrical current through a conductor when the electrical circuit is complete. The circuit is the path made up of the conductors through which the current passes.

Electrical currents and flowing water. Currents of electricity behave much as does water flowing through pipes, even though the streams of electrons do not flow through a wire in the same manner as water through a pipe. When water flows through a pipe, there is friction between the water and the pipe. This friction decreases the current of water through the pipe. The longer the pipe the greater the friction and therefore the less the current of water that will flow through it for any given pressure; the smaller the diameter of the pipe the greater the resistance to the flow of water and the less the current through it. This is only another way of saying that for a given pressure we get a bigger flow of water through a large pipe than through a small one, because the resistance is less.

When a stream of electrons, that is, a current, passes through a substance, even a good conductor, the electrons find difficulty

in forcing their way among and through the atoms. The opposition to their flow is electrical friction and is called resistance. Long

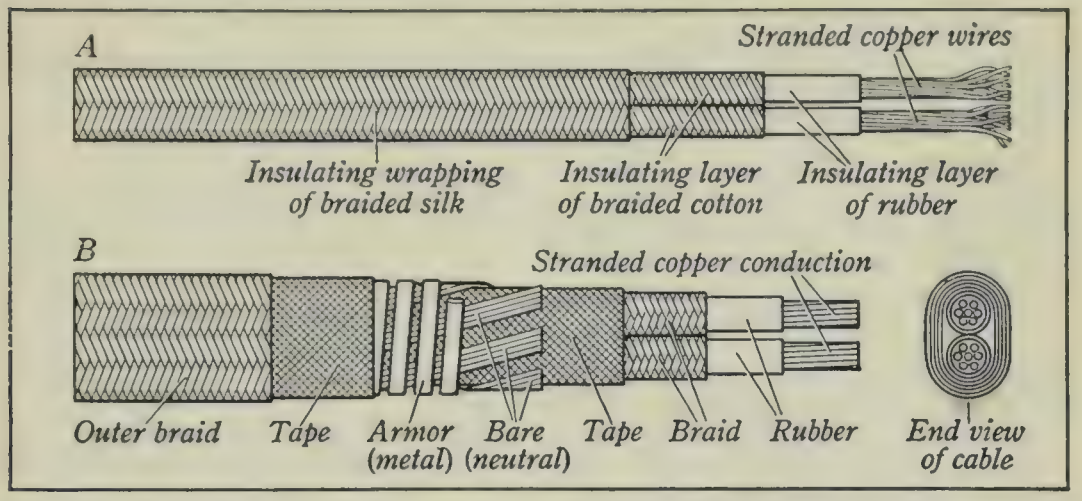

FIG. 256. *A*, lamp cord; *B*, service entrance cable. What are the conductors and what are the insulators in *A*? Note that *B* has three conductors, one of which is the "bare neutral." The flat metal "armor" bound round the bare neutral wires increases conduction. How? The oval at the right of *B* shows how the cable looks from the end. This cable has five insulating layers. What are they?

wires have more resistance than short wires, and small wires have more resistance than large ones. Also, the greater the resistance of a wire the smaller the current which will flow through the wire. The unit of electrical resistance is the ohm.

Insulation. Wire conductors are commonly covered with some sort of insulating, or nonconducting, material (Fig. 256, *A* and *B*). Such material prevents short circuits; that is, it prevents electrons from escaping from the wire by running off on some other conductor which may touch the wire.

Whenever wires are connected to terminals in making a complete circuit, all the insulation must be scraped off the ends of the wires so that the terminals make good contact with the bright metal of the wire.

Complete circuits. No current will flow at any time unless there is a complete circuit. Usually the complete circuit consists of two wires, one on which the current flows to the appliances and one on which it returns to the source of energy. Sometimes the circuit is completed by grounding it, that is, by connecting one of the wires from the cell or the generator to an iron water pipe or to the metal frame of an automobile. When wires are thus

grounded, the earth or the metal frame takes the place of a return wire. Thus, in an automobile the spark plugs are connected to the cylinder head, which acts like a wire in grounding the current, and one terminal of the storage cell is connected to the metal frame, which serves as a wire.

Self-test on Problem XXII–A. (*Do not write in the book.*) **1.** An electrical current consists of a stream of __(?)__ passing through a conductor.

2. *Volts* force *ohms* of electrical current through a *conductor.*

3. A foot of wire offers *more* resistance to a *current* of electricity than two feet of wire of the same kind and size.

4. If the E.M.F. in a given conductor is *increased,* the current through the conductor will be *diminished.*

5. In order to have a flow of current the circuit must be *almost* complete.

6. An iron water pipe is a *poor* conductor of electricity.

Problem XXII–B · How is Chemical Energy Changed to Electrical Energy in Electrical Cells?

The simple electrical cell. ***Experiment 62.*** Does a simple electrical cell produce a current? Connect an electric bell to the copper and zinc strips as indicated in Fig. 257. Fill a tumbler or a battery jar with sulfuric acid of about 1200 rating, which you can secure from an automobile service station or which you can prepare by adding one part of concentrated sulfuric acid to twenty parts of water. [CAUTION: *Be sure to pour the acid into the water, not the water into the acid.*] When all is ready, but not before, plunge the two plates into the acid. What does the ringing of the bell when it is connected to the simple electrical cell prove?

*All electrical cells transform chemical energy into electrical energy. Every electrical cell has two plates of different materials in a liquid which will carry a current. The simple cell, which was invented by an Italian, Volta, in about the year 1800, was the first electrical cell. It consists of strips of two different metals, copper and zinc, put into a vessel of water containing a few drops of sulfuric acid (Fig. 257). The copper plate becomes positively charged and the zinc plate negatively charged by the chemical

action of the sulfuric acid. Thus electrical energy is secured from chemical energy rather than from kinetic energy, as was the case when the fountain pen became negatively charged and woolen cloth positively charged by rubbing the two together. The action of the acid on the metals produces a difference in E.M.F. between the two metals.

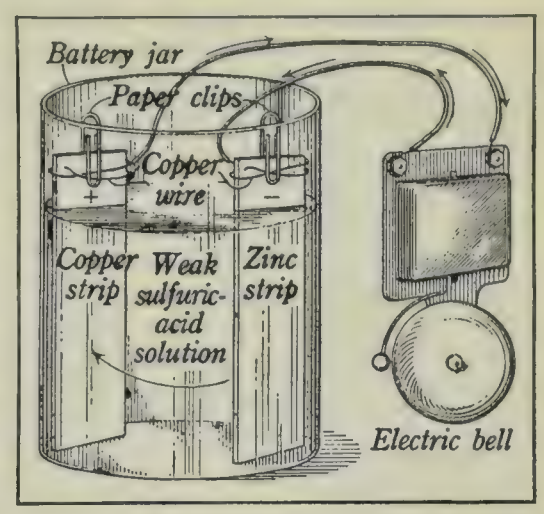

FIG. 257. A simple electrical cell. The paper clips are not a part of the cell. They merely serve to press the wires firmly against the plates. What is the function of the electric bell here?

How the simple cell operates. If the tops of the metal strips of a simple cell are connected by a conductor, such as a copper wire, a stream of electrons is at once forced out through the conductor from the zinc strip to the copper strip. The electrons flow down the copper strip and are carried through the acid solution back to the zinc strip. This stream of electrons, which is the current, continues to pass through every part of the circuit as long as the chemical energy is being transformed into electrical energy in the cell. The direction in which the electrons flow through the circuit is exactly opposite to the direction of current flow as indicated by electrical engineers and by electricians.[1] They mark all their machines, instruments, and drawings as if the current were flowing from positive to negative. This incorrect idea began with Benjamin Franklin before scientists really knew for certain in which direction the current does flow. He had only two guesses and he chose the wrong one. Franklin's plan of indicating current direction through a circuit has become so universally used throughout the world that it seems impossible to change it. Therefore, in all diagrams and discussions henceforth we shall follow everyday practice and shall say with the electricians that the current flows from positive to negative although we know that it actually flows from negative to positive.

[1] *Electrician* (e lek trish'un): one who works with electrical appliances, materials, or currents.

***The dry cell.** The simple electrical cell is of no practical value, because, as it acts, its pressure (that is, its voltage) becomes weaker, and therefore its current rapidly becomes weaker also. For practical purposes use is made of a dry cell. The two plates of different materials in this cell are of carbon and zinc (Fig. 258). The dry cell contains a paste made chiefly of ammonium chloride and manganese dioxide. The dry cell serves well if it is used only for short periods and is allowed to rest between the periods. The dry cell is convenient because it does not occupy much space and because it will not break or leak. The dry cell is not entirely dry, since the liquid in the paste carries the current through the cell. Dry cells are used in operating flashlights, doorbells, electrical toys, radio sets, and spark coils in gas engines, and in many other ways.

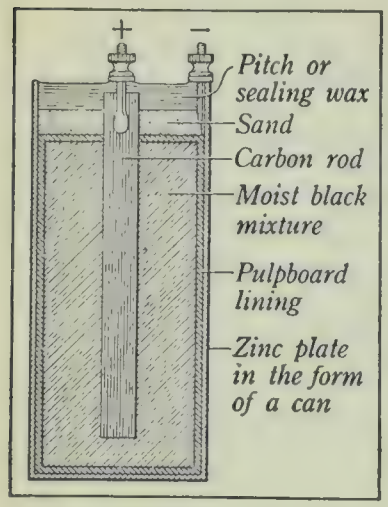

FIG. 258. Compare the dry cell with the simple cell. (See "To the Student," p. xvi)

Storage cell. Another common type of electrical cell is the storage cell.

Experiment 63. How is a simple storage cell made and how is it used? Place two large strips of lead in a battery jar. Fill the jar about three-fourths full of "battery acid" (sulfuric acid diluted with distilled water) obtained from your local service station. Connect two dry cells to the lead plates as in Fig. 259, *A*. Can you observe any changes taking place on the two lead plates? After about a quarter of a minute disconnect the two dry cells and connect a small electric bell in their place (Fig. 259, *B*). What happens?

*In this experiment the storage cell was first charged. To begin with, the plates were the same — both lead. As the storage cell became charged, the surface of one plate was changed to brown lead peroxide. It was then able to send a current, because the two plates were of different materials. It was then discharged through the bell. As it discharged, further chemical changes resulted in coating both plates with the same material. When the two plates became the same again, the current ceased to flow.

A storage cell does not store electricity; it stores chemical energy. When it is charged, electrical energy is transformed into chemical energy in the cell. When it is discharged, the stored chemical energy is transformed again into electrical energy. Not all the electrical energy used in charging the storage cell can be recovered from the cell as electrical energy when the cell is later discharged, for some of this energy is transformed to heat energy and hence it is not usable. Some more of the energy is used in converting a part of the liquid to gas.

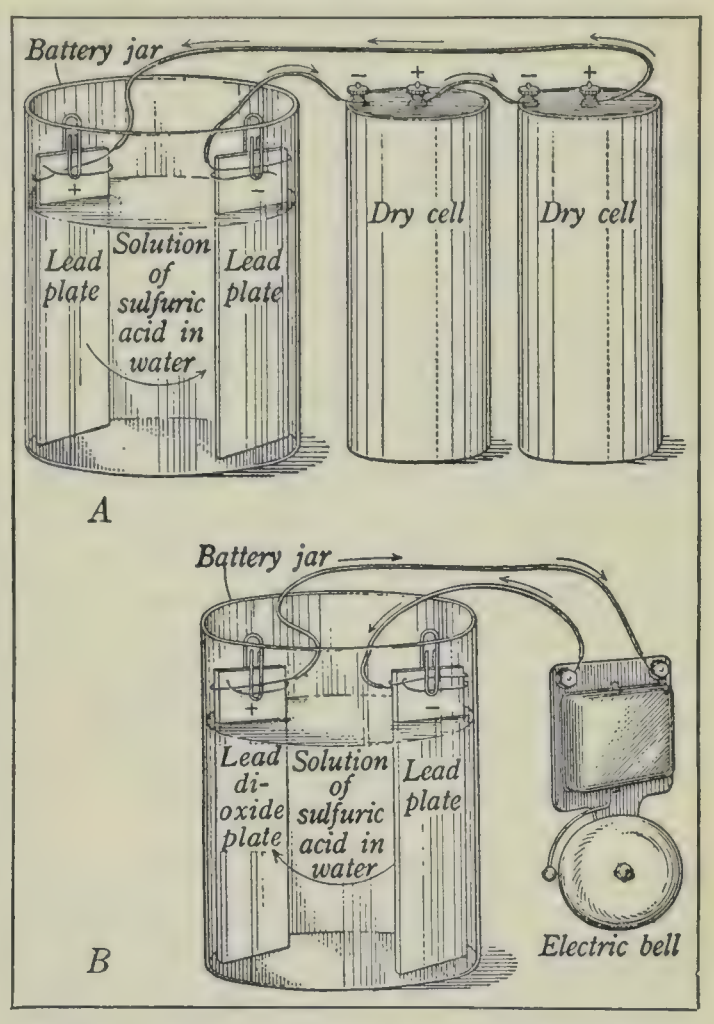

FIG. 259. *A*, charging a storage cell; *B*, discharging a storage cell. Is the direction in which the current flows the same in both diagrams? Is the same plate plus in both diagrams?

Water has to be added frequently to the cell, chiefly because the water evaporates but also because water is broken up by the electrical current into hydrogen gas and oxygen gas. The oxygen combines with the lead to form the brown coating of lead peroxide on the plus plate.

Commercial storage cells are used in operating automobiles and radio sets, in powerhouses, in submarines, in telephone exchanges, and the like.

*Summary. Electrical cells transform chemical energy into electrical energy. Every electrical cell consists of two plates of different materials in a liquid which will carry a current.

In every electrical cell one plate is always consumed, and some element is always deposited on the other plate.

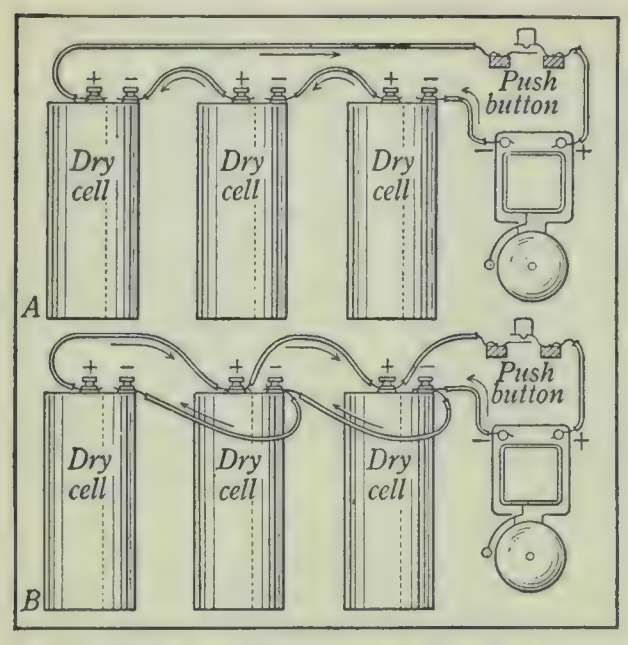

FIG. 260. *A*, cells connected in series; *B*, cells connected in parallel. Summarize the differences between series connections and parallel connections of cells in a battery

Series connections and parallel connections. Usually several cells are used together instead of one alone. Two or more cells connected together are called a battery. Cells in a battery are usually connected in series; that is, the — pole, or terminal, of the first cell is connected to the + pole, or terminal, of the second cell, the — pole of the second to the + pole of the third, and so on (Fig. 260, *A*). The — pole of the last cell is never connected directly to the + pole of the first cell. Instead these poles are connected to the "load," which in this case is the electric bell. Sometimes the cells are connected in parallel, as in Fig. 260, *B*. When cells are connected in parallel, all the + terminals are connected together and all the — terminals are connected together. While the terminals of the load may be connected with the + and — terminals of any of the cells, the results are better if the load is connected to either of the end cells.

Self-test on Problem XXII–B. (*Do not write in the book.*) 1. An electrical cell *usually* has two plates of the same material.

2. Electrical cells transform *mechanical* energy into *electrical* energy.

3. The *dry* cell contains *no* liquid.

4. The electrons through a circuit travel *from* the positive *to* the negative pole.

5. A charged storage cell contains *kinetic* energy.

6. A storage cell can furnish a current only after its two *poles* have been made *alike*.

7. When cells are connected in series, the *plus* pole of the first cell is connected with the *plus* pole of the next cell.

8. When an electric cell is used continuously, its current becomes *weaker* because its E.M.F. becomes *less*.

Problem XXII-C · What is the Relation between Magnetism and Electricity?

Magnetism and electricity. ***Experiment 64.*** Does a conductor which is carrying a current have magnetism? Is it surrounded by a magnetic field? Scrape all the insulation from a few inches of the middle of a copper wire [1] about two feet long. Sprinkle some iron filings on a sheet of paper. Dip the bare part of the wire into the filings. Do the filings stick to the copper? Place the wire above the needle of a compass. Is the needle turned? Now connect the two ends of the wire to the terminals of a dry cell [1] and repeat both experiments. Are the filings attracted? Is the compass needle moved when the wire is placed above it? Is a wire which is carrying current surrounded by a magnetic field? Break the circuit by disconnecting the wire at one terminal. Does the wire still have a magnetic field? Answer with a complete statement the question at the beginning of this experiment.

Electromagnets. In 1819 Oersted, a Danish scientist, discovered that a conductor carrying a current of electricity is surrounded by magnetic lines of force like those round a magnet. This discovery led to the invention of the first electromagnet by Henry, an American, in 1828. Electromagnets are used in almost all modern electrical machines.

Experiment 65. Does a coil carrying a current have an *N* pole and an *S* pole like a bar magnet? Make a coil of a piece of insulated copper wire thus: Starting about a foot from one end of the wire, wind it round a pencil or a pen, leaving the last foot of wire unwound. Connect the *bare* ends of the wire to the terminals of a dry cell. Bring a compass near each end of the coil in turn

[1] To the Teacher. For such experiments as this and those that follow, No. 18 copper annunciator wire with paraffined cotton covering will be found excellent. Since dry cells are intended for intermittent use, it is best, whenever possible, when using dry cells in experiments to connect a push button into the circuit as in Fig. 260. Using dry cells for momentary currents will lengthen their "lives" greatly.

(Fig. 261). Is the coil a magnet while the current is flowing through it? How do you know? Does it have a north pole and a south pole? How do you know? Disconnect one end of the coil from the cell. Is the coil now a magnet? Connect the ends of the coil to the opposite terminals of the cell from those to which you connected them before. Is the coil a magnet now that the current is flowing through it in the opposite direction? Is the same end an *N* pole that was the *N* pole before? Summarize the results of this experiment.

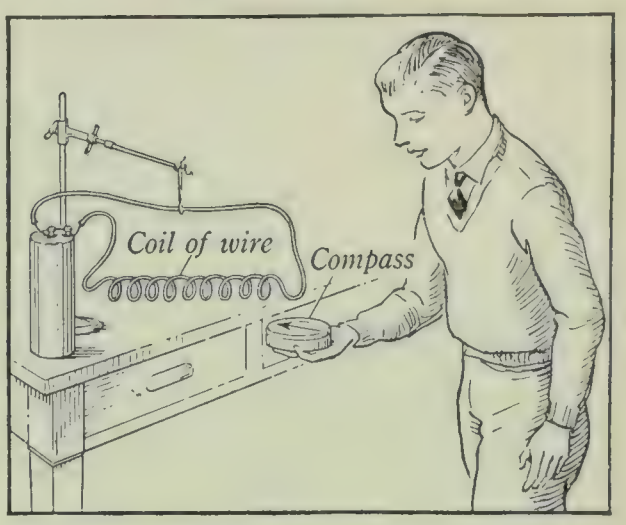

FIG. 261. Testing a current for magnetism.
Special Report: The work of Joseph Henry. (Consult an encyclopedia)

Experiment 66. Is the magnetism of a coil carrying a current increased when certain substances are put inside the coil as a core[1]? Connect the bare ends of the coil to the terminals of the dry cell. Place the coil on the table and place

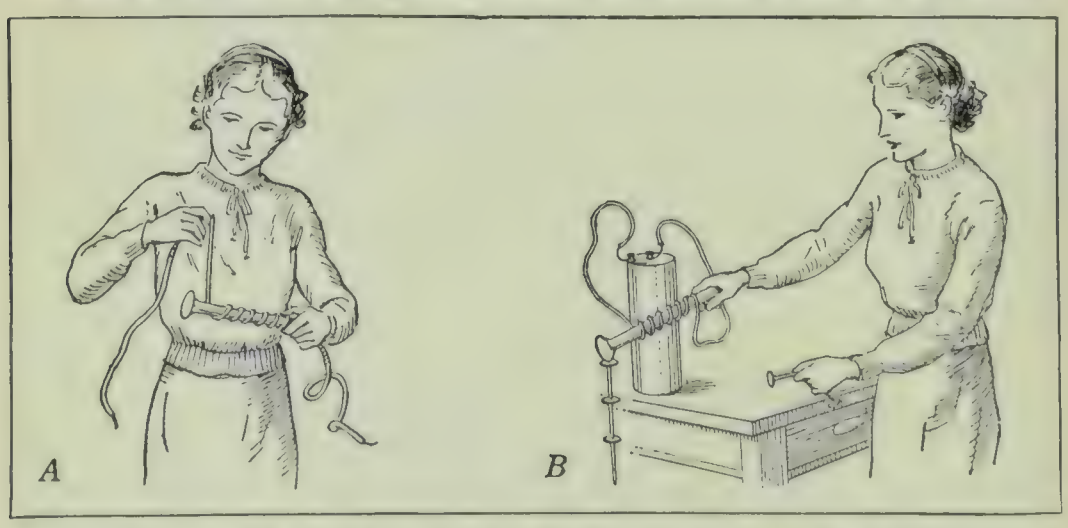

FIG. 262. Making (*A*) and testing (*B*) an electromagnet. What will happen to the nail in *B* when the coil is disconnected from the cell? Explain

the compass near one end of it and far enough away so that it is only slightly deflected[2] by the magnetism of the coil. Without chang-

[1] *Core:* a central body; for example, the core of an apple.
[2] *Deflect* (de flekt'): to turn from its position or path.

ing the position of the coil, insert in the coil, one after the other, a wooden pencil, a metal pencil, a glass rod, a copper wire, and a large iron nail. Is the magnetism of the coil made stronger when any of these substances is used as a core for the electromagnet? Which substance makes the electromagnet strongest?

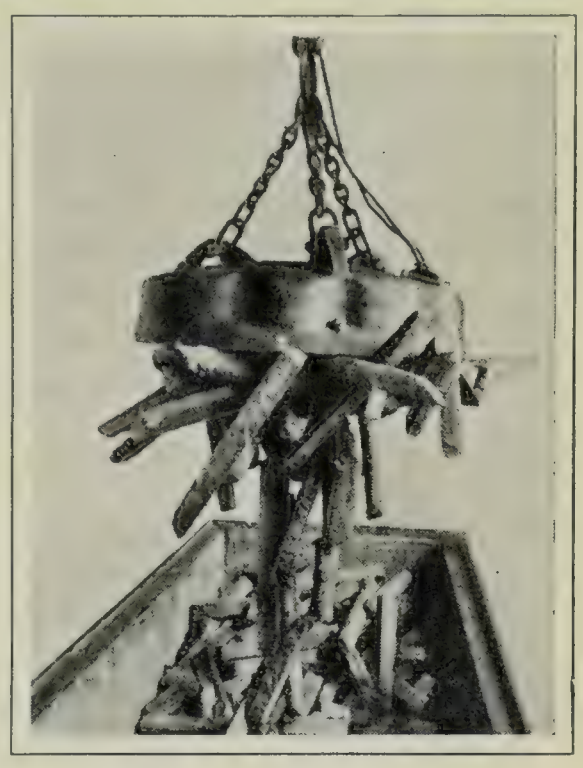

FIG. 263. The coil of this great electromagnet is wound around an iron core which is fastened to the iron case. The magnet is placed over a pile of iron bars. Direct current is sent through the coil. Immediately the magnet picks up its load of iron bars—five tons at a time. The magnet is then moved with its load to the point desired, the current is turned off, and the bars fall. Why? Are the iron bars magnets while they are held by the large magnet? Explain

An electromagnet (Fig. 262, *A*) is made of a coil of insulated wire wound round a soft-iron bar or cylinder, called the core. The soft-iron core greatly increases the strength of the coil magnet by causing it to act like a very strong bar magnet (Figs. 262 and 263). The electromagnet is a magnet only while the current is flowing through the coil (Fig. 263). (Prove this statement.) The iron core, however, usually retains some magnetism after the circuit is broken; that is, after one of the wires has been disconnected and the current ceases to flow. The poles of the magnet can be changed by reversing the current; that is, by sending the current through the coil in the opposite direction. (Prove this statement.)

Induced currents. We have already learned that a piece of iron or steel becomes an induced magnet when it is brought into a magnetic field. This magnetic field may be that of a bar magnet, a U-shaped magnet, or an electromagnet. In 1831 Faraday, an English physicist and chemist, made the important discovery that an electric current is made to pass through a circuit if part of the circuit is moved through a magnetic field. This does not mean

that electricity is *produced*. We have stated earlier that there are millions of free electrons scattered through all parts of a circuit. The motion of the conductor in the field merely starts them streaming in one direction through the circuit. Thus mechanical energy is changed to electrical energy. Currents produced by moving a conductor in a magnetic field are called induced currents.

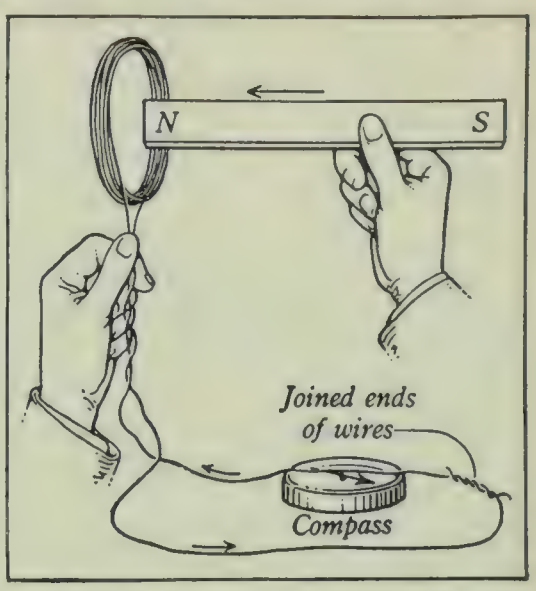

FIG. 264. The principle of the alternating-current generator is illustrated by the coil, the magnet, and the complete circuit made by joining the ends of the wire from the coil. What is the function of the compass?

Generators. ***Experiment 67.*** How can mechanical energy be transformed into electrical energy in a simple generator? Make a coil of at least one hundred turns of insulated copper wire (No. 18 or 22). Make a handle for the coil by twisting together the wires below the coil. Complete the circuit by twisting the bare ends of the wire together so as to make firm contact. Place a compass under the wire with the needle and the wire parallel. Quickly thrust a magnet through the coil (Fig. 264). Observe the compass. Is the needle deflected? Is any current induced in the circuit by moving the magnetic field through the coil? Let the magnet remain stationary[1] in the coil. Is the needle deflected? Quickly pull the magnet back through the hole. Is the compass needle again deflected? Is it deflected in the same direction when you quickly push the magnet through the coil as when you pull it back through the coil? Repeat this experiment as before except that you keep the magnet stationary and first thrust the coil quickly over the end of the magnet, then pull it off quickly, observing the compass needle as before. Does the current change direction when the field is reversed?

***How are alternating[2] currents induced?** You have just been illustrating the principle of a simple alternating-current dynamo,

[1] *Stationary* (sta'shun a ry): remaining in the same place.

[2] *Alternate* (al'ter nate): to continue to change back and forth from one condition to another. Thus, alternating current constantly changes, that is, reverses its direction through the circuit.

or generator. A generator is a machine used to transform mechanical energy into electrical energy. When a conductor cuts across the magnetic lines of force of the magnet, electrical pressure, or E.M.F., is always produced or induced in the conductor. If the circuit is complete, or closed, this induced E.M.F. forces a current through the circuit. If the direction in which the conductor is cutting the magnetic lines of force is reversed, at once the direction of the E.M.F. is reversed. Consequently the current immediately flows through the circuit in the direction opposite to that in which it was flowing before. In other words, changing the direction in which the magnetic lines are cut by the coil reverses the current through the coil, that is, causes it to alternate in the closed circuit.

***How does an alternating-current generator operate?** A commercial generator is never so simple as the arrangement used in Experiment 67. Instead of the back-and-forth, or vibration, motion used in Experiment 67, a rotary, or whirling, motion is always used in a real generator. Fig. 265 illustrates the operation of the magnet type of alternating-current generator, in which the coil, or armature, rotates in a magnetic field. The ends of the loop of wire which represents the armature in Fig. 265, A, are each attached to one of the slip rings. The rings rotate with the armature. The brushes do not rotate. One end of a brush, which is usually a piece of carbon, touches the ring all the time that the ring is rotating. The rest of the circuit is attached to the other ends of the brushes. Thus when the side of the loop armature marked x is at the top and is coming toward you as the loop armature rotates, a current is generated in the loop armature in the direction of the arrow (Fig. 265, A). The current therefore goes out through the brush marked A, travels through the external[1] circuit in the direction indicated by the arrows to brush B, and through the slip ring B to the other end of the armature. But when the armature has turned enough so that the side of the wire marked y is at the top and is coming toward you while x is at the bottom and is going away from you, the current is going out through B and in through A (Fig. 265, B). The current has al-

[1] *External* (eks tur'nal) : on the outside ; here, outside the generator, which ends at the slip rings.

ternated, or changed its direction, through the external, or outer, circuit twice for each complete rotation of the armature.

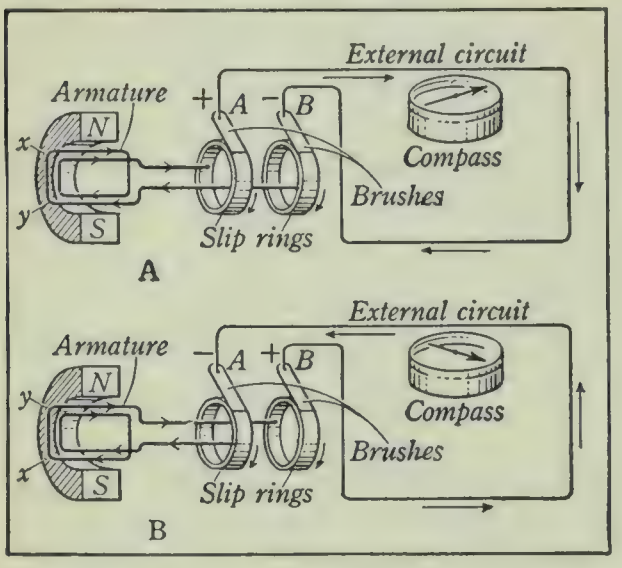

FIG. 265. A, diagram of a simple alternating-current (A.C.) generator; B, diagram of the same generator when the armature has turned one half rotation farther around. If the poles of the U-shaped field magnet were reversed, the induced current through the circuit would be reversed. Why?

Commercial alternating-current generators. A.C. (alternating-current) generators provide the current for most commercial purposes. Commercial A.C. generators for generating large currents use electromagnets for their magnetic fields instead of bar magnets. An electromagnet has many turns of wire instead of only one loop as in Fig. 265, A and B. Also, in the great A.C. generators used for generating most of the electric power, the magnetic field rotates round a stationary armature. The revolving type of A.C. generator illustrated in Fig. 265, in which the armature rotates in a stationary field, is made only in small sizes which find relatively few uses.

*__Direct-current generators.__ D.C. (direct-current) generators are somewhat similar to alternating-current generators; in fact a D.C. generator generates A.C., but the A.C. is changed to D.C. by the commutator, as will now be explained. Instead of having slip rings as do A.C. generators, D.C. generators have one ring, which is cut lengthwise into two or more parts. This ring is called a commutator. The commutator rotates, but the brushes do not. The commutator in Fig. 266, A, is a copper ring cut into two equal parts with insulating material between. The two ends of the coil are attached each to half the commutator. When the current is induced in the loop of the armature marked x, so that it flows toward the commutator, it flows out through brush A and in

through brush *B*. When the armature has rotated halfway round to its position in Fig. 266, B, the current in the coil has alternated and is now flowing through *y* toward the commutator. But *y* now makes contact with brush *A*, so that the current *still* goes out through *A* and comes in through *B*, as before. Thus the commutator keeps the current always flowing in the same direction through the external circuit.

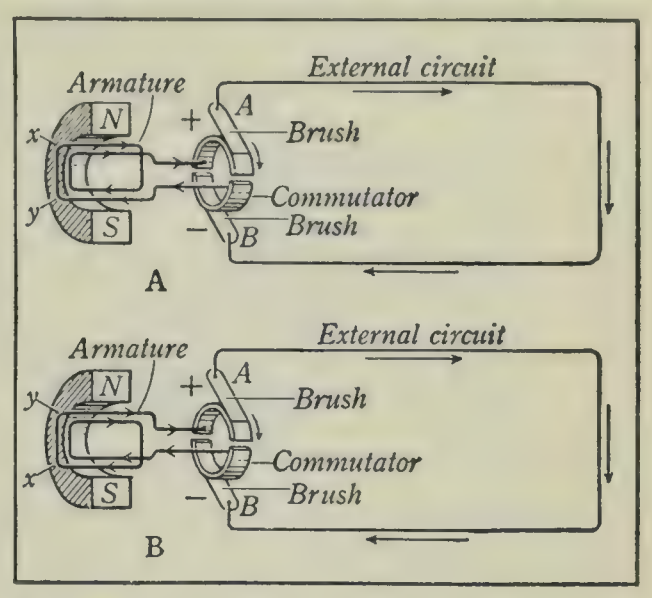

FIG. 266. Compare this diagram of a simple direct-current (D.C.) generator with that of the simple A.C. generator (Fig. 265, p. 396). (See "To the Student," p. xvi)

Direct current (D.C.) generators are always of the revolving-armature type; that is, the armature rotates in a stationary magnetic field. This type of generator supplies the current used to run most streetcars, to charge storage batteries, and to some extent to light incandescent lamps.

Sources of electrical energy. The armatures of generators are usually turned by steam turbines. Thus the chemical energy of the fuel is transformed into heat energy, the heat energy into mechanical energy of the rotating field or rotating armature, and the mechanical energy into electrical energy. Water turbines find considerable use in generating electricity. Water above a falls possesses potential energy. This water is led down through pipes to water turbines (Fig. 44, p. 71) in a powerhouse. These turbines turn the fields or the armatures of dynamos. Thus mechanical energy is changed to electrical energy. In some places where winds are strong and steady, the mechanical energy of wind is used to turn windmills, and these turn the fields or armatures of dynamos. Steam engines find some use in generating current.

The electric motor. We have learned that an electrical generator transforms mechanical energy into electrical energy. An electric

motor serves an exactly opposite purpose. An electric motor transforms electrical energy into mechanical energy. An electric motor

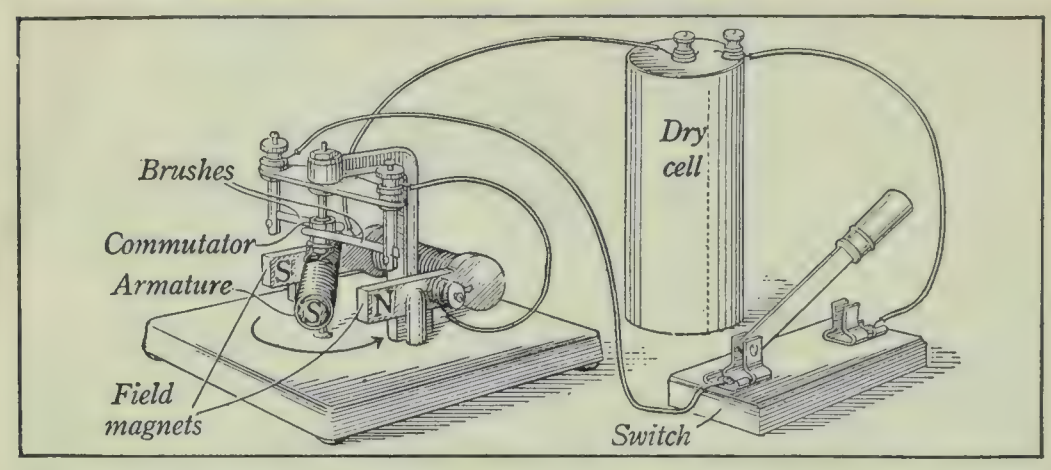

Fig. 267. Diagram of a simple electric motor. Can you trace the current from the plus pole of the dry cell through the motor and back to the minus pole of the cell when the switch is closed? Can you explain why the armature rotates in the direction indicated by the arrow?

is very much like a generator or dynamo. In fact, if you were to purchase a small D.C. motor, the same machine could be used either as a generator or as a motor. The chief difference between an electrical generator and an electric motor is this: In a generator the rotation of the armature in the magnetic field induces a current. In a motor (Fig. 267) a current is sent through both the armature and the field. This current makes electromagnets of the coils of the armature and of the field. The attraction and repulsion between the magnetic poles of these coils and the magnetic poles of the field push and pull the armature around, causing it to rotate. Thus, in a generator rotation produces current, while in a motor current produces rotation.

Small electric motors similar in type to that shown in Fig. 267 are used with both D.C. and A.C. in such small motor-driven machines as vacuum sweepers, sewing machines, electric fans, and the like. There are other relatively simple types of electric motor, but these can be used only with D.C. A.C. motors are in general far more complex in design. The study of these must be delayed to later science courses.

The electric motor is of great importance and value in transportation, not only because it is used to drive electric cars and

electric locomotives but also because recently it has come to be used to turn the propellers of ships. Cogs on the armature shaft turn other cogs on the axle of the car wheels or on the propeller shaft. The electric motor, moreover, has wide uses in manufacturing plants and in and about the home.

Self-test on Problem XXII–C. (*Do not write in the book.*) **1.** A wire through which a stream of electrons is flowing is *often* surrounded by a magnetic field.

2. An effective electromagnet could be made by winding *bare* copper wire around a bar of *aluminum.*

3. An electromagnet loses *little* of its magnetism when the current ceases to flow through the coil.

4. One end of an electromagnet attracts the north pole of a bar magnet. If the current through the electromagnet is reversed, the same end of the electromagnet will attract the __(?)__ pole of the bar magnet.

5. In an electrical *generator* a coil of wire is made to move through a *magnetic* field of force.

6. A generator (1) transforms mechanical energy into electrical energy; (2) produces electrical energy; (3) transforms chemical energy into mechanical energy; (4) transforms chemical energy into electrical energy; (5) transforms mechanical energy into chemical energy.

7. In an *A.C.* generator the current flows out through the circuit always in the same direction.

8. An *A.C.* generator is equipped with a commutator.

9. In an *A.C.* generator the *brushes* turn with the armature, but the *slip rings* do not.

10. The armature of an electric motor is made to turn by the attraction and repulsion of the poles of the *armature* and the *field.*

Problem XXII–D · How can Electrical Energy be Used in Electrolysis?

Electrolysis. *Electrolysis* is the process of breaking up a chemical compound into its parts by sending a direct current of electricity through it. Thus, if D.C. is sent through water which is made a good conductor by adding to it a little sulfuric acid (Fig. 268), bubbles of hydrogen gas form on the — terminal and bubbles of oxygen gas on the + terminal.

We call this process the electrolysis of water; that is, the electrolysis of water is the breaking up of the chemical compound

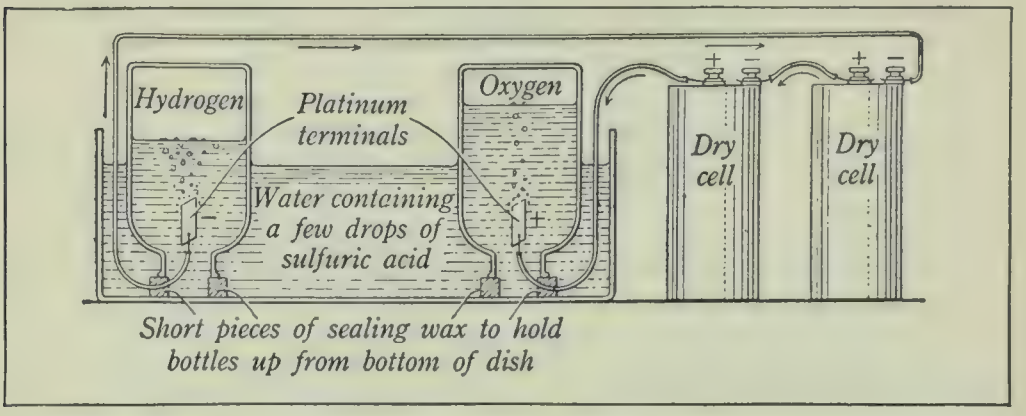
Hydrogen
Platinum terminals
Oxygen
Dry cell
Dry cell
Water containing a few drops of sulfuric acid
Short pieces of sealing wax to hold bottles up from bottom of dish

Fig. 268. Why does twice as much hydrogen as oxygen result from the electrolysis of water?

water, or hydrogen oxide, into its parts, the elements hydrogen and oxygen, by electricity. Electrolysis is used in many industries and in all kinds of plating with metals, such as silver, gold, and copper (as in the following experiment).

Electroplating. ***Experiment 68.*** How can copper be plated with copper by electrolysis? Dissolve some blue vitriol (copper sulfate) in water. Attach two pieces of copper screen to wires connected with two dry cells in series (Fig. 269). Allow the current to pass through the solution for an hour. What changes can you see in the two pieces of screen? What conclusions do you make from the experiment?

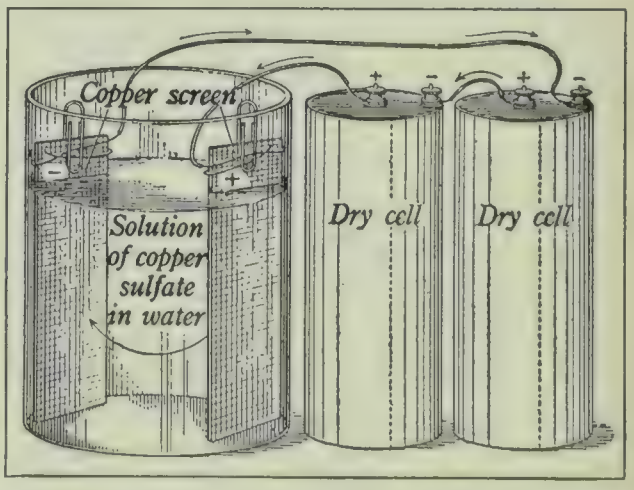

Fig. 269. Connect into the circuit in place of the screen marked — a clean silver coin or the carbon rod from a worn-out dry cell. What happens?

The metal which is deposited, or plated, upon another metal by electrolysis is quite pure. Pure copper is obtained by the method illustrated in Experiment 68, from impure copper bars.

The bars of impure copper, just as they are produced from the copper ores, are hung in a tank which contains copper sulfate solution. These bars are connected with the conductor leading from the + pole of a source of direct current. Thin sheets of pure copper are also hung in the tank of copper sulfate solution. These sheets are attached to the wire leading from the — pole of the source of current. The copper is carried by the current from the copper bar through the copper sulfate solution and deposited evenly on the sheets of pure copper. The substances which made the copper bar impure then settle to the bottom of the tank.

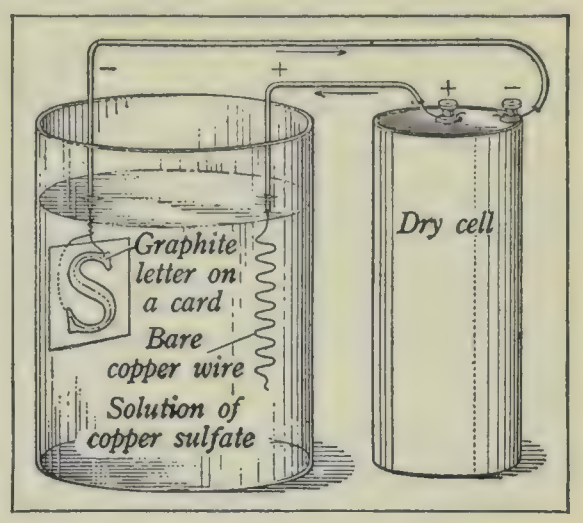

FIG. 270. Would this experiment be successful if you exchanged the places of the graphite letter and the copper wire in the copper sulfate solution? Explain

Electrotyping. ***Experiment 69.***[1] How is electrotyping done? With a *very soft pencil* draw a broad letter on a visiting card. Thread a fine copper wire from the minus terminal of the cell through the graphite[2] letter on the card, so that the wire makes contact with the letter in at least four places. Be sure that the bare wire makes a good *contact* with graphite. Complete the circuit as in Fig. 270. Let the current pass through the circuit for two hours. If you are careful you can remove the copper letter from the card.

The plates from which this book were printed were made in the same manner as the letter which you just copperplated. After the page of the type is set up, a wax impression of the page of type is made. Before the type is stamped into the wax, the wax has finely powdered graphite brushed over it. The graphite keeps the wax from sticking to the type. The graphite, which is a very good conductor of electricity, sticks to the wax and makes the face of the impression a good conductor. Wax would not be a

[1] This experiment was suggested by Dr. W. A. Gorton.

[2] The "lead" of a lead pencil is made not of lead, but of graphite, a form of carbon. Coal is composed chiefly of carbon.

good conductor. The impression is connected with the minus terminal from a source of direct current and is immersed in a solution of a copper salt. A bar of copper is connected to the positive terminal. Pure copper is carried by the current to the graphite and deposited upon it in a thin layer. When the copper plate on the graphite is thick enough, the wax impression and its copper plate are removed from the copper salt. The copper plate is separated from the wax and given a metal backing for greater strength. It is then ready for printing.

Self-test on Problem XXII–D. 1. *Alternating current* is used in electrolysis.

2. In the electroplating of a silver spoon, the spoon is connected with the *minus* plate of the cells or the generator furnishing the current.

3. In electrotyping, *copper* is plated on *wax.*

4. In electrolysis of water, twice as much *oxygen* as *nitrogen* is produced.

Self-test on Scientific Principles. What applications of this principle are made in machines described in this chapter: "Like magnetic poles repel each other and unlike magnetic poles attract each other"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. In the electrotyping process, why is the wax impression connected with the minus terminal instead of with the plus terminal?

2. Why is direct current used for electrolysis instead of alternating current?

Exercise on Scientific Method. Sir Humphry Davy (1778–1829), son of a Cornish wood-carver, became perhaps the greatest chemist of his time. He discovered the anesthetic[1] "laughing gas" (nitrous oxide) as well as the nature and properties of several elements. He invented the first electric arc light and the Davy safety lamp. This lamp saved the lives of thousands of coal miners by preventing gas explosions in the mines. He is, however, most famous for his work on the electrolysis of water and the preparation of pure metals from their compounds by electrolysis. One example will illustrate his methods: Although most chemists of his time believed that potash and soda were metals, he thought they were probably compounds. He set about finding out. He set a damp lump of potash on a platinum disk, which he connected with the

[1] *Anesthetic* (an es thet'ik): a substance that prevents pain in surgical operations.

negative pole of a battery. He then connected the potash with the positive pole. Soon tiny drops of what looked like mercury appeared on the platinum disk. He concluded that this new substance was an element and a metal (potassium).

What phases of scientific method (p. 9) are illustrated by the steps in this experiment with potash?

Exercises on Scientific Attitudes. 1. What scientific attitude (pp. 12 and 13) is illustrated by Henry's use of Oersted's earlier work (p. 391)?

2. Thomas A. Edison (1847–1931) has been called "America's gift to civilization." He began life as a poor boy with a burning ambition to be an inventor. As a boy he served as a newsboy on a train. He set up a laboratory in the baggage car, where he experimented during his spare time. One day while experimenting with phosphorus he set fire to the car. He was discharged immediately and was put off the train at the next station. He continued his experimenting, however, in a laboratory which he set up at home. He read the books on electricity by Faraday, whom he considered the "perfect experimenter."

Edison made few, if any, great original discoveries. His genius consisted in making practical uses of the discoveries of others and improving existing inventions. His patience and care in his work knew no limits. A partial list of his inventions and improvements on inventions includes the phonograph, the electric lamp, the motion-picture machine, talking pictures, the mimeograph, the storage battery, electrical generators, electric trains, and a number of appliances used in telegraphy and telephony.

What scientific attitudes (pp. 12 and 13) do these incidents in Edison's career indicate that he possessed?

Edison was a friend of Charles P. Steinmetz (1865–1923), the great American electrician who by means of mathematics developed methods, and by experimenting discovered many principles, of great importance in modern electrical engineering.

Special Reports. 1. Examine the commercial storage cell, make a diagram of it, and make a report on it.

2. How does the Edison storage cell differ from the lead storage cell? In what ways is each superior to the other? (Consult textbooks of physics or electricity.)

Books for Reference

Bond, A. R. The Scientific American Boy at School. Munn & Co., Inc., New York.

Lunt, T. S. Everyday Electricity. The Macmillan Company, New York.

Zerbe, J. S. Motors. Cupples & Leon Company, New York.

Chapter XXIII · Electricity in the Home

Questions this Chapter Answers

What are transformers, and how are they used?

How may one reduce the danger from electrical circuits in the home?

How is the electrical circuit in the home constructed, and how do its various parts function?

What types of electrical appliances are generally used in the home, how are they constructed, and how do they operate?

How expensive is the general use of various common types of electrical appliances found in the home?

Problem XXIII–A · How is Electrical Energy Brought into the Home?

***Increasing use of electrical energy.** Until a few years ago electricity found little use in homes. After people began to use electric lamps in place of candles, kerosene lamps, and gas lamps, other electrical appliances[1] and conveniences began to find a place in the home. The electric iron began to take the place of the old-fashioned flatiron, the vacuum cleaner did much of the work formerly done by the broom, heating devices such as electric stoves, toasters, and curling irons made their appearance, and small motors began to be used for sewing machines, washing machines, and fans, and for a variety of uses in the kitchen (Fig. 271).

The use of electrical appliances is rapidly spreading, because it is becoming more and more easy to get electrical service. Great power plants are sending their lines into the country districts. Where commercial electric service is not yet obtainable, people are installing their own power plants, consisting of a dynamo run by a water turbine or by a gasoline or steam engine.

Transformers. Most of the electrical energy supplied for use in the home and in industry is in the form of A.C. This A.C. is usually generated in great amounts by huge generators often many miles from where the electrical energy is used (Fig. 272).

[1] *Appliance* (ap pli'ance): a device or tool.

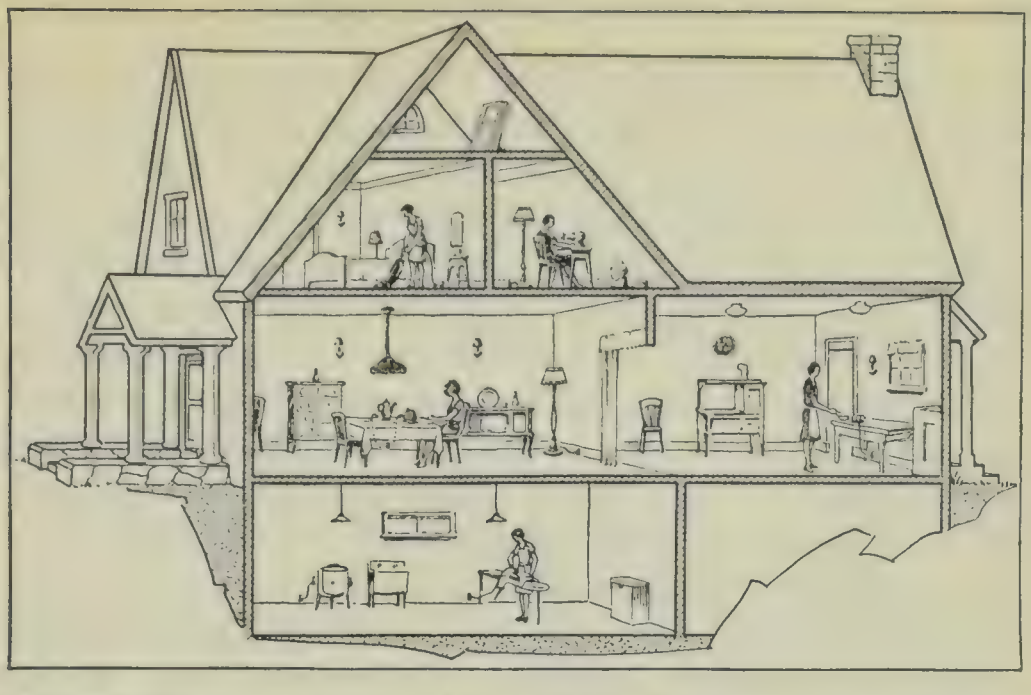

FIG. 271. How many electrical devices for the home can you name besides those shown in the picture?

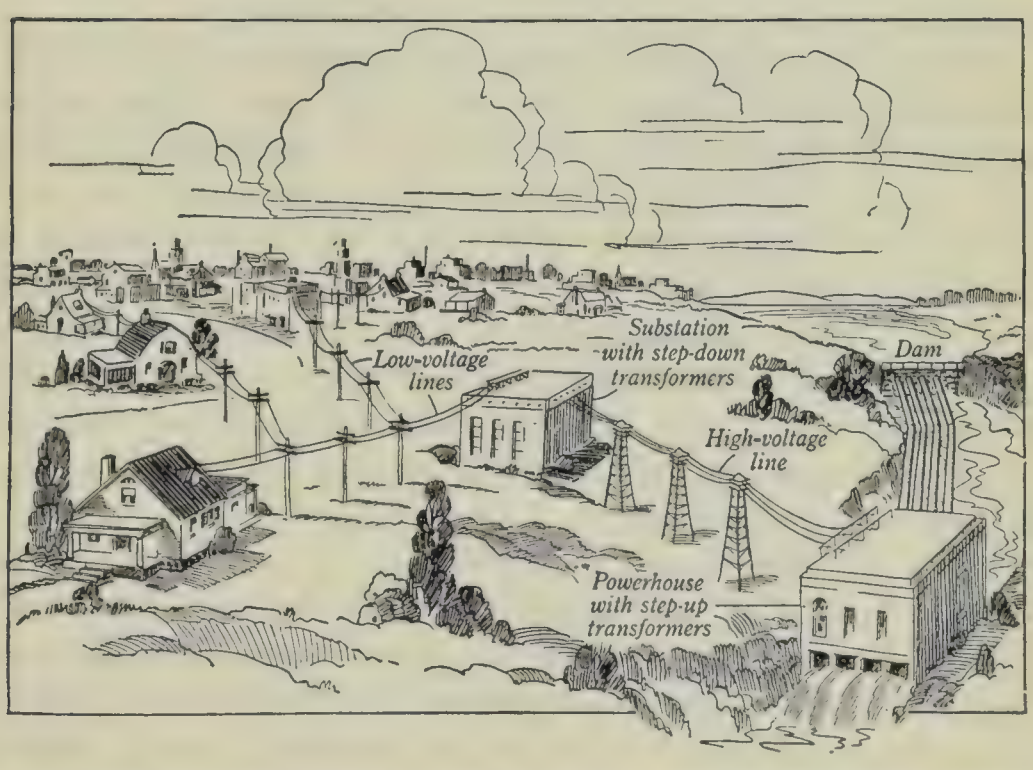

FIG. 272. From powerhouse to home. Can you prove that electrical energy is secured indirectly from the sun?

It is sent from the powerhouses through wires. Some of this electrical energy is transformed into heat energy in the wires and is radiated off and hence lost on the way. Less electrical energy is wasted by being transformed into heat if a small number of amperes of current is sent at high pressure (E.M.F.) than if a large number of amperes is sent at low pressure, or low voltage (see Glossary). The A.C. generated in the powerhouses is therefore first sent through transformers. These "step up," or raise, the E.M.F. and reduce the current. Sometimes the electrical pressure in long-distance power lines is stepped up to an E.M.F. as great as 220,000 volts. Such high-voltage currents are called high-tension currents.

Electric currents cannot be sent into houses at high voltages without great danger. Therefore they are sent from the power lines through a second set of transformers near our homes. These transformers "step down" (reduce) the pressure to a voltage which is safe to use in lamps, motors, and other household appliances, and at the same time they increase the current.

Danger from defective wiring and appliances. The E.M.F. in house lines usually ranges from 104 to 125 volts. These voltages are safe if used properly with first-class appliances which are kept in excellent repair. But there are many records of serious accidents and even death from defective lighting fixtures and appliances. Be especially careful not to touch any grounded conductor, such as a water faucet, gas pipe, stove, heating radiator, or hot-air register while you are handling electric lighting fixtures or appliances. Also be careful in handling lights and appliances when you are standing on the concrete floor of the basement or the garage.

***The electrical circuit in the house.** If your house has been recently built, you must look outside, usually on either the front or the back porch, to see where the current enters from the service main, or service wire. If your house is older, you will probably locate the entrance of the service entrance cable in the basement or perhaps in the attic. The service entrance cable brings the electrical energy from the service main to the house. In the older houses this cable enters a metal pipe at the house wall and extends inside this pipe to the service distribution cabinet. In the newer

houses a special, heavy cable carries the wires directly to the service distribution cabinet without the need for the protection given by the metal pipe.

If you were to examine the service entrance cable you would find within it three wires. Two of these wires are "hot" wires, so called because one carries the electrical energy from the power line to the house and the other carries it back to the power line. No current would flow in the wires unless the circuit were complete with two wires. The neutral wire is grounded once at a point where the wire leaves the power main for the house and again, usually by connecting it with a water pipe, after it enters the house (Fig. 273). The two "hot" wires with the neutral wire serve the purpose of two circuits of two wires each. Each of the outside wires makes a complete circuit with the neutral wire (Fig. 273). Connecting either "hot" wire with the neutral wire commonly provides an E.M.F. of 110 volts. This voltage is suitable for most lamps and electrical appliances. Connecting both "hot" wires together provides 220 volts. This E.M.F. is suitable for an electric range.

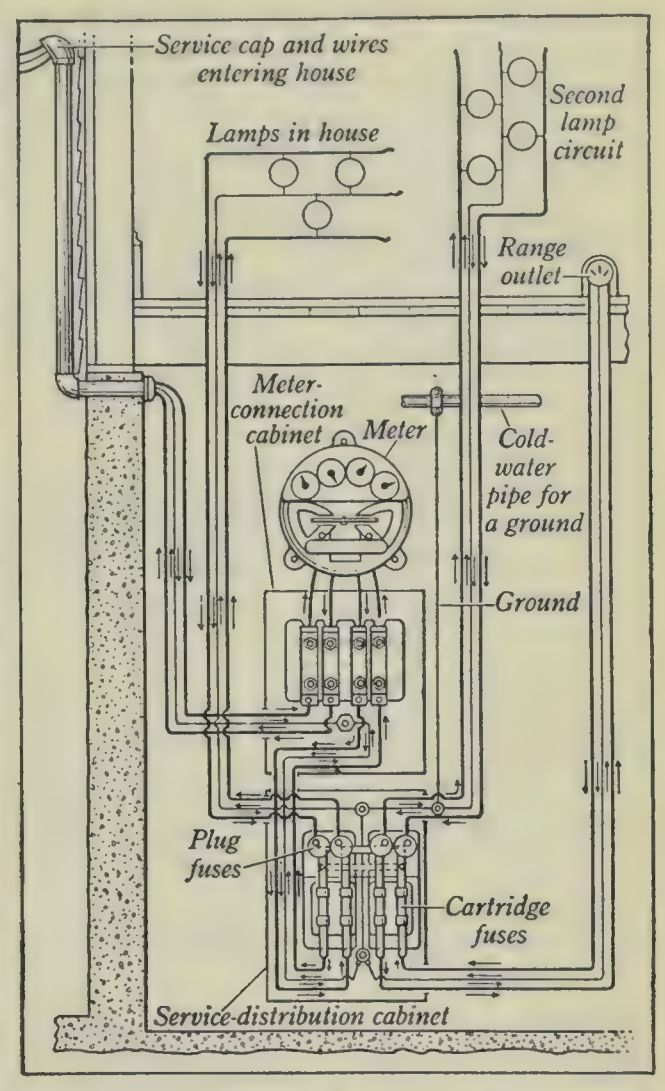

FIG. 273. Diagram showing how electrical energy enters the home. Can you trace the circuit from the service main through the meter, to the service cabinet, and from it to the lamps and the range? In many houses only two of the three wires are used for the lamp circuits, one a "hot" wire and the other the neutral wire (see Fig. 279, p. 413)

The service distribution cabinet is an iron box. This box contains the main house switch and the switch for the line leading

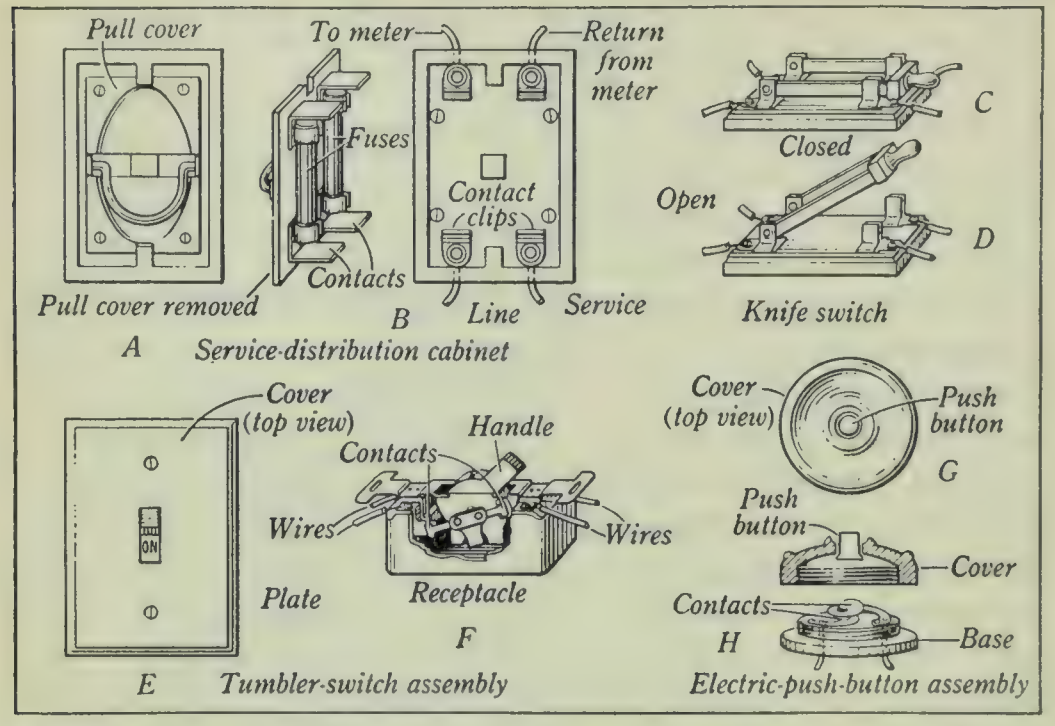

FIG. 274. Various types of switches. **Special Report:** Carefully take apart a cord switch or other type not pictured here. Examine its parts and describe its operation. Put it together again

from the meter to the distributing panel. It also contains the necessary fuses.

Switches. The switch completes or breaks an electric current. When the switch is closed, the circuit, or path, is complete and the current can flow. But when the switch is opened, the circuit is broken and no current can flow through it.

Switches are of several types. In modern houses the main house switch, or master switch, consists of a plug which is pushed into the service distribution cabinet to complete the circuit and is pulled entirely out of the cabinet to break the circuit (Fig. 274, *A* and *B*). Switches in the distribution cabinet for branch circuits are usually knife switches (Fig. 274, *C* and *D*). Wall switches are of several types, but all are similar in general construction. Each closes the circuit in one position and opens it in the other (Fig. 274, *E* and *F*). A doorbell push button is still another type of switch (Fig. 274, *G* and *H*). It differs from

the others mentioned by being equipped with a spring which breaks the circuit when the pressure on the button is released.

The main house switch is a safety device. Whenever anything is wrong with the electric service in the house or whenever the electricians want to make any changes in wiring, they first open the house switch so that no current can flow into the house while they are working. The knife switches and the wall switches serve to turn on or to shut off the current in the branch circuits.

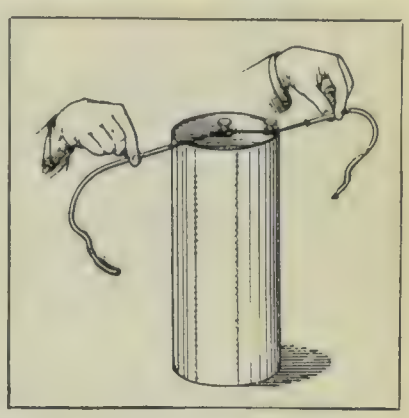

FIG. 275. Can you name any electrical appliances which change electrical energy into heat energy?

Fuses. *Experiment 70.* Does electrical friction, or resistance, produce heat? Short-circuit a cell by connecting a very small copper wire across the terminals of the cell (Fig. 275). One of the small single copper strands of ordinary lamp cord is excellent for this experiment. Does the wire get hot? Do not keep the short circuit across the cell terminals longer than is necessary, because much current is used, thereby greatly shortening the life of the dry cell.

The fuse is another safety device. We learned in Chapter XXII that when an electric current travels through a circuit it has electrical friction, or resistance. Mechanical friction produces heat; so does electrical friction, or resistance.

Some kinds of conductors have greater resistances than others. Good conductors have small, or low, resistances. Poor conductors have large, or high, resistances. An electric current passing through a conductor that has a low resistance does not produce much heat, but the same electric current passing through a conductor that has a high resistance produces much heat. Fuse wires have lower melting temperatures as well as somewhat higher resistances than the copper wire used in the house circuit. Therefore fuse wires are made hotter by the current than are the copper wires.

Experiment 71. How do fuses protect the house? Scrape all the insulation from the wire at two points each of which is about three inches from an end of a length of No. 18 copper wire about ten

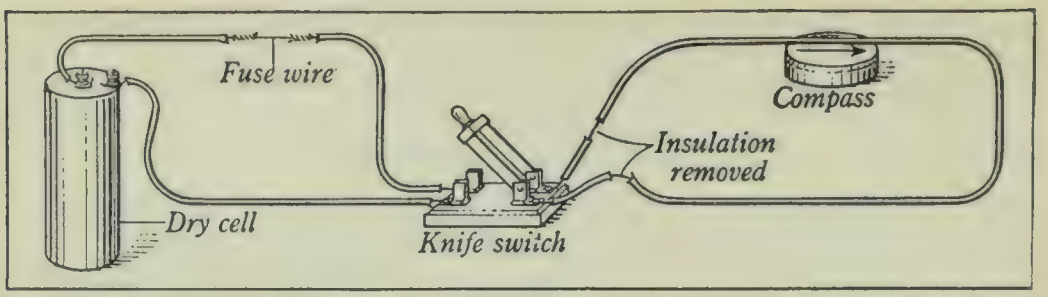

FIG. 276. When the circuit is short-circuited, the current divides and part of it flows over each path. Most of it flows over the path having the lesser resistance. What are the two paths here, and over which will the greater part of the current flow?

feet long. Tightly twist together four strands of one-ampere fuse wire so as to make a single four-ply strand. Connect in series, as in Fig. 276, a dry cell, a double knife switch, the piece of fuse wire, and the long copper wire. This represents the wiring in a house. The short copper wires from the cell to the switch are service wires, the switch and the fuse represent the arrangement shown in Fig. 273, and the long copper wire represents the wiring within the house. The compass is used to indicate when current is flowing in the circuit. Complete the circuit by closing (pushing down) the switch. Does the compass show that current is flowing through the circuit? Short-circuit the house wiring by touching firmly together the two bare spots in the wire. What happens? Does the current still flow in the circuit? Answer with a complete sentence the question with which this experiment begins.

House fuses. House fuses are usually of the types shown in Fig. 277. Cartridge fuses are usually made to carry currents of more than thirty amperes. Such fuses are used in the service distribution cabinet and in special circuits requiring heavy currents, such as the circuit to the electric range. Plug fuses are used in the distributing panel for branch circuits. Plug fuses are usually made to carry currents up to thirty amperes. It is unwise to use a fuse of higher rating than that which is proper for the circuit which the fuse is intended to protect. The number is stamped on the fuse. A plug fuse screws into a socket as does an electric lamp. The fuse wire in a plug fuse completes the circuit by connecting the side with the bottom of the socket.

How does a fuse function? If too much current is being used by the lamps and appliances connected in any house circuit, or if a short circuit occurs, the heat produced in the wires may be great

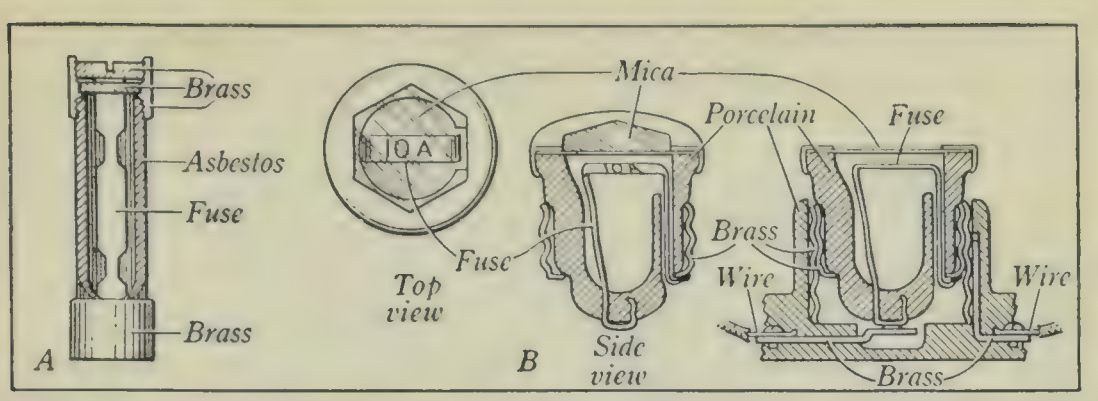

FIG. 277. *A*, cartridge fuse; *B*, plug fuse. Can you trace the circuit from one wire connected to the socket to the other wire connected to the socket?

enough to melt the wire or even to set fire to the house unless the circuit is properly protected by a fuse. The fuse wire gets hot faster than the copper wire, and fuses, or melts, at a lower temperature. It therefore fuses, or "blows," before the rest of the wire gets hot enough to do any damage. When it fuses it breaks the circuit and stops the flow of current just as if you opened the switch, as in Experiment 71. When the trouble in the circuit has been repaired, but not before, another fuse should be put into the socket. The circuit is then the same as before the fuse was melted.

Sometimes, when a fuse blows, people remove the burned-out fuse plug and place a nickel or a penny in the socket. The coin completes the circuit just as the fuse wire did, by touching the metal at the bottom and the side of the socket. *This is a dangerous thing to do*, because putting in the coin has not removed the trouble in the house circuit. It has merely removed the protection which a fuse would give. Whenever a fuse melts, the safe thing to do is to report the trouble to the electric company or to consult an electrician. It is dangerous for you to experiment with the circuit.

Circuit breakers. The place of fuses is rapidly being taken by a new device called a circuit breaker. This device resembles a knife switch. When the current becomes too great for the safety of the circuit, the circuit breaker automatically opens, breaking the circuit. When the trouble has been located and repaired, the circuit breaker is closed like a knife switch, completing the circuit. The circuit breaker is not injured by great currents, as is a fuse, and serves again and again.

The electric meter. After the wires leave the master switch they go to the electric meter (Fig. 278). This meter registers the amount of electrical energy which has been used. Electrical energy is measured in kilowatt-hours. The number of volts of E.M.F. multiplied by the number of amperes of current which have flowed, multiplied by the number of hours the current has been flowing, gives the watt-hours of energy used. Since 1000 watt-hours equal a kilowatt-hour, we must divide the number of watt-hours by 1000 to find the number of kilowatt-hours. For example, if an E.M.F. of 110 volts sent a current of 10 amperes through the circuit for two hours, the number of watt-hours of energy used would be $110 \times 10 \times 2 = 2200$ watt-hours. The number of kilowatt-hours would be 2200 divided by 1000, which would be 2.2 kilowatt-hours. If electrical energy cost 5 cents per kilowatt-hour, the bill would be $2.2 \times 5 = 11$ cents.

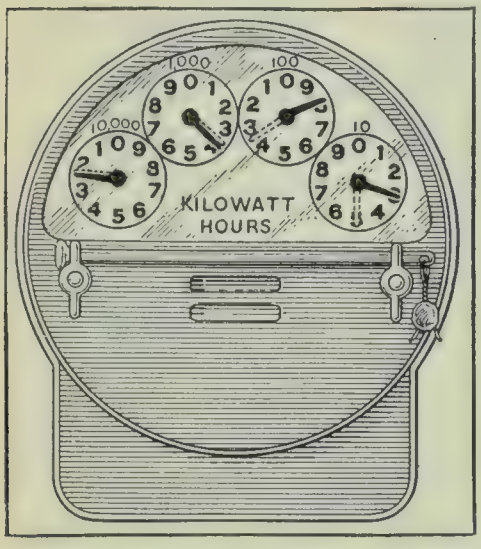

FIG. 278. The dotted lines show the positions of the hands when the meter was last read. The reading was then 2335 kilowatt-hours. What is the reading now? What is the bill at 5 cents per kilowatt-hour?

Self-test on Problem XXIII–A. (*Do not write in the book.*) 1. *Large* current at *small* E.M.F. is sent through a long-distance power line.

2. A step-up transformer increases the *current* through the wires.

3. The cable which brings electrical energy into the house has *four* wires, of which *one carries* the current and the *others are* neutral.

4. A fuse wire *completes* the circuit when the current becomes unusually *great.*

5. A fuse wire has *higher* resistance and is a *better* conductor than the copper wire which composes the rest of the circuit.

6. The expression "blowing a fuse" means that the fuse wire ___(?)___.

7. An electrical meter measures the electrical *current* used in *amperes.*

FIG. 279. Electric lamps are connected in parallel, that is, across the wires. What is the advantage of connecting them in this way? Of the two wires used here one is "hot" and the other is neutral (see Fig. 273, p. 407)

Problem XXIII–B · How is Electrical Energy Used in the Home?

***Outlets.** Outlets are installed at various places in the house to provide current for various electrical appliances. Two wires lead to every outlet (Fig. 279). When a plug is pushed into the two holes in the convenience outlet, the circuit is completed through the lamp or appliance connected with the plug. When the circuit is completed, the current comes to the outlet on one wire and leaves on the other. Cord such as is used to connect a plug with a floor lamp or a table lamp, a vacuum sweeper, or other electric appliance, appears to contain only a single wire. But if you remove the outer cloth and rubber insulation from this flexible cord (use a piece which is not a part of any circuit), you will discover that it is "stranded"; that is, that it consists of *two* small copper cables, each made up of a bundle of small copper wires, or strands. Stranded wire is more easily bent and is less likely to break than solid wire of the same size. One small cable carries the current from the outlet to the lamp or appliance; the other

carries the current back to the outlet. Lamps and appliances are connected in parallel (Fig. 279), just as are the cells in Fig. 260, p. 390.

Electrical appliances. Appliances such as the electric washing machine, the electric sewing machine, and the vacuum cleaner make use of small motors to change the electrical energy into mechanical energy. Where electric power costs 5 cents per kilowatt-hour, these electric motors will do their work for an entire hour for about $1\frac{1}{4}$ cents for the washing-machine motor, $\frac{3}{8}$ cent for the sewing-machine motor, and $\frac{7}{8}$ cent for the vacuum cleaner.

Electric appliances such as the flatiron, heater, toaster, and stove change electrical energy into heat energy. The heating elements of each of these devices are coils of high-resistance wire. In passing through these coils the current produces enough heat to make the coils of wire very hot. Electric heating is too expensive to be used for a whole house. A radiant electric heater costs 3 cents per hour when electricity costs 5 cents per kilowatt-hour. At the same rate it costs $2\frac{3}{4}$ cents per hour to run an electric coffee percolator, 3 cents for an electric table stove, 3 cents for a waffle iron, and $2\frac{1}{2}$ cents for a toaster. These devices, however, are not usually operated steadily for an hour.

Electric lamps. An electric lamp works on the same principle as the electric heater. A fine wire made of the metal tungsten is attached (usually in the form of a coil) to a support in the lamp globe. This wire is called the filament of the lamp. When current passes through this filament, its high resistance produces enough heat to cause it to become incandescent and to produce a bright, white light.

The electric doorbell. In the electric doorbell (Fig. 280) the circuit leads first from the terminal to the electromagnet, thence to the bottom of the little post which holds up the contact screw. (Note that the contact screw is insulated at the bottom of the metal frame.) The circuit then leads across the contact screw to the iron vibrator or armature, which touches the contact screw, and from the vibrator through the metal frame. The metal frame serves as a wire to conduct the current to the other terminal of the bell.

How the electric current causes the armature to vibrate, that is, to move back and forth, is explained thus: When the push button is pressed down, the circuit through the bell is complete. The electromagnet becomes magnetized and attracts the iron vibrator to it, pulling the vibrator away from the contact screw. As soon as the vibrator leaves the contact screw the circuit is broken and the current stops flowing through the electromagnet. The electromagnet therefore loses its magnetism and no longer attracts the vibrator. The spring on the vibrator then pushes the vibrator back so that it again touches the contact screw. Immediately the circuit is made complete again, and the electromagnet again attracts the armature, breaking the circuit. This action keeps repeating itself as long as the push button is held down.

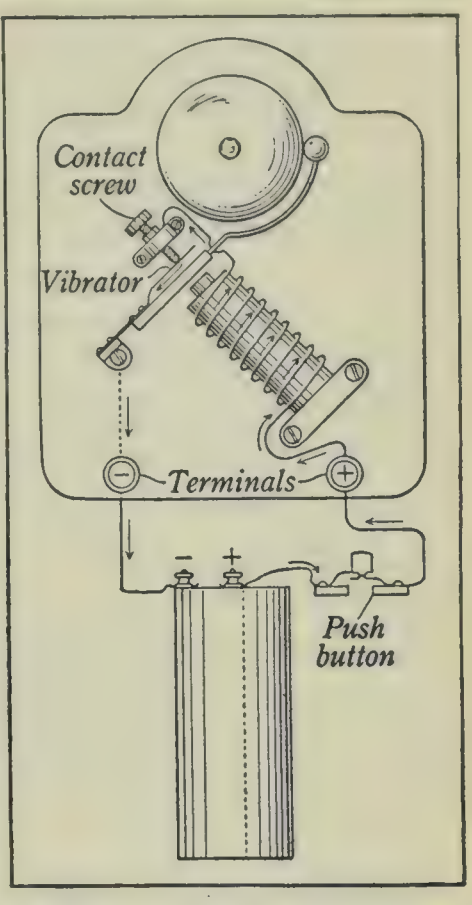

FIG. 280. Can you make a similar diagram in which a U-shaped electromagnet is used in place of the straight form shown here?

Experiment 72. Would the bell ring if you reversed the current, that is, sent it through in the opposite direction? Try it. What happens to the electromagnet when you reverse the current through it? Test it with a compass to find out what happens to it. Answer each of these questions with a complete sentence.

Electrical energy for doorbells. A battery of two dry cells connected in series is frequently used for doorbells. Dry cells are not especially satisfactory for this purpose, because their chemical energy is used up after a few months and they have to be replaced. For this reason, in houses which are equipped with A.C. the house service wires frequently have a small transformer connected with them to take the place of the battery of dry cells in ringing the doorbell. This transformer steps down, or reduces, the E.M.F. through the bell. The price of the bell-ringing transformer is about

twice that of two dry cells, but through a long period of use the transformer is cheaper, because some types can be run continuously for ten hours at a cost of one cent. The transformer is also much more convenient than the dry cells for this purpose, because it needs no attention and will last for many years.

Self-test on Problem XXIII–B. (*Do not write in the book.*) **1.** The electrical cord connecting a vacuum sweeper with an outlet contains *three* wires.

2. It is *much more* expensive to use electrical energy to turn motors in household appliances than to furnish heat.

3. Electric house lamps are *always* connected in *series*.

4. If the armature of a doorbell were made of brass, the doorbell would *scarcely* ring.

5. In an electric lamp electrical energy is transformed into __(?)__ energy and __(?)__ energy.

6. A doorbell would ring if its frame were made of *brass*.

7. The armature of a doorbell vibrates because the core of the electromagnet *keeps most* of its magnetism when the current is made to stop flowing through the electromagnet.

8. The most economical source of energy for doorbells is a *dry cell*.

Self-test on Organization of Facts. List all the cautions with respect to the use of electricity given in this chapter.

Self-test on Scientific Principles. **1.** State in your own words the principle of conservation of energy (see Index). How many examples of this principle can you state from this chapter?

2. How many applications can you find in this chapter of the principle "Like magnetic poles repel each other, and unlike magnetic poles attract each other"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. **1.** What changes would you have to make in an electric bell to make it a single-stroke bell instead of a vibrating-armature bell?

2. Why should the electric iron be turned off or disconnected at the outlet whenever one leaves the room, even if for only a minute?

3. Compare an electric motor with an electric generator. (See "To the Student," p. xvi.)

Exercise on Scientific Attitudes. MICHAEL FARADAY (1791–1867), an English scientist, began his scientific work when a boy by making crude experiments with electricity. Later he was employed by Sir HUMPHRY DAVY, another famous English scientist, to act as a laboratory "chore boy." At the age of twenty-four he was made Davy's laboratory assistant. He spent eighteen years studying the work of other men in electricity — Volta, Galvani, Oersted, Ampere, and Arago — carrying on experiments of his own meanwhile. He made the discovery that electrical currents can be produced with magnets. This discovery has been called "the greatest experimental result ever attained by an investigator." This discovery made electric generators possible. He made the discovery, also, that an electric current in one wire will induce or produce a current in another wire. This principle is employed in the modern generators and electrical motors as well as in the telephone and numerous other electrical appliances.

What scientific attitudes (pp. 12 and 13) do these incidents of Faraday's career indicate that he possessed?

Projects. 1. Diagram a system of electrical connections in which a bell and a buzzer are both connected to the same battery of two dry cells and are so arranged that the bell will be rung by a push button at the front door and the buzzer will be rung by a push button at the back door. Set up the apparatus according to your diagram and see whether your solution of the problem is correct.

2. Make a diagram for the following problem: Locate a bell in each of two rooms and a cell in one room only. Arrange the wiring so that the push button in either room will ring only the bell in the other room. Set up the apparatus to test the correctness of your diagram.

3. Can you solve the preceding problem by using only three wires which go from one room into the other? This system of wiring is known as the "return call" circuit.

Special Report. Examine the wiring in your home. Locate the service distribution cabinet, the main house switch, the fuses, and the meter. Make a diagram showing how the wires enter and leave these devices.

Books for Reference

COLLINS, A. F. The Book of Electricity. D. Appleton-Century Company, Inc., New York.

LUNT, T. S. Everyday Electricity. The Macmillan Company, New York.

MORGAN, I. The Boy Electrician. Lothrop, Lee & Shepard Co., Boston.

UNIT IX · *The Use of Energy in Communication*

PROBLEMS DISCUSSED IN THIS UNIT

If you have observed the actions of dogs, cats, and other animals, you have seen that they are able to communicate with one another to some extent. Ancient men doubtless were also able, by means of sounds and simple movements, to convey to each other a few important ideas, such as "food," "danger," and the like. During the ages since man first appeared on the earth, he invented one by one many ways of communicating. Human language became constantly more complete and extensive. Man learned to communicate his ideas to others at greater and greater distances, by means of fire signals, smoke signals, the beating of drums, and flashes of light. At length he learned to write. Then finally he learned to send written messages by runners, by horse, by carrier pigeon, by wagon, by ship, by train, and by airplane.

Within the last century the growing understanding of electricity has resulted in inventions which have greatly extended communication. The telegraph brought distant parts of the world into immediate communication. By its means the newspapers became able to print foreign news on the same day on which the events occurred. The invention of the telephone proved of equal importance with the telegraph in extending and improving means of communication. Within the lifetimes of most people now living the radio has been perfected to the extent that makes possible almost instant communication with all parts of the world. Television is now being developed. Who can guess what further means of communication may be developed? The problems discussed here are these:

What are the nature and characteristics of sound?
How is a knowledge of sound applied in musical instruments?
How are the telegraph and the telephone used in communication?
How are the radio and television used in communication?

Chapter XXIV · Sound in Communication and Enjoyment

Questions this Chapter Answers

How are sounds produced?
How do sounds travel?
What produces the differences in loudness, pitch, and quality?
How are echoes caused?
How do we hear?
What should one know about the care of the ears?
What are the principal classes of musical instruments?
How are the phonograph and the dictaphone constructed, and how do they operate?
How does the player piano operate?
What sort of sound instrument is the human voice?
How are telegraph and telephone systems constructed, and how do their various parts operate?

Problem XXIV–A · What are the Nature and Characteristics of Sound?

How sounds are produced. If you stretch a rubber band between your hands and have somebody pull the band in the middle and then let go of it, you will observe two phenomena: you will hear a musical sound given off by the band and you will see that the middle of the band is moving back and forth, or vibrating (Fig. 281, *A*). If one end of a knitting needle is stuck into a pencil or a stick (Fig. 281, *B*), and if you then bend and release the free end, you will again observe the same phenomena that you observed with the rubber band. You will hear a humming sound and will see that the free end of the needle is vibrating.

Experiment 73. How does a tuning fork give off a sound? Strike the end of a tuning fork with a hammer made by sticking a one-hole rubber stopper on the end of a pencil. Quickly stick the end of the fork into water. Do you observe any phenomena which indicate that the fork is vibrating? Strike the fork again and touch the end lightly against your ear. Do you observe the same phenomena that you observed with the rubber band and the needle (Fig. 281)?

FIG. 281. **Exercise on Scientific Method (Using Check Experiments)**: Each of these experiments with vibrating bodies serves as a check on the other. Explain

*If you were to continue your experiments, you would find that whenever a sound is being made, the body that is producing the sound is in vibration.

***What carries sound?** Suppose that two balloons carrying passengers were to rise together at the same rate of speed, having started close enough together so that the passengers in one balloon could talk with those in the other. They would note that as they rose the sounds of their voices became less loud. If the balloons should remain at the same distance from each other and should continue to rise, it would be constantly more and more difficult for the sounds made in one balloon to be heard in the other. As the air became less dense the sounds would become fainter. The reason is that all sounds pass with difficulty through a partial vacuum, and not at all through a perfect vacuum.

FIG. 282. If the boy and a fish were at equal distances from the point where the stone struck the water, the fish would hear the sound first. Explain

*Have you ever been diving or swimming under water while somebody struck two pieces of iron or two stones together under

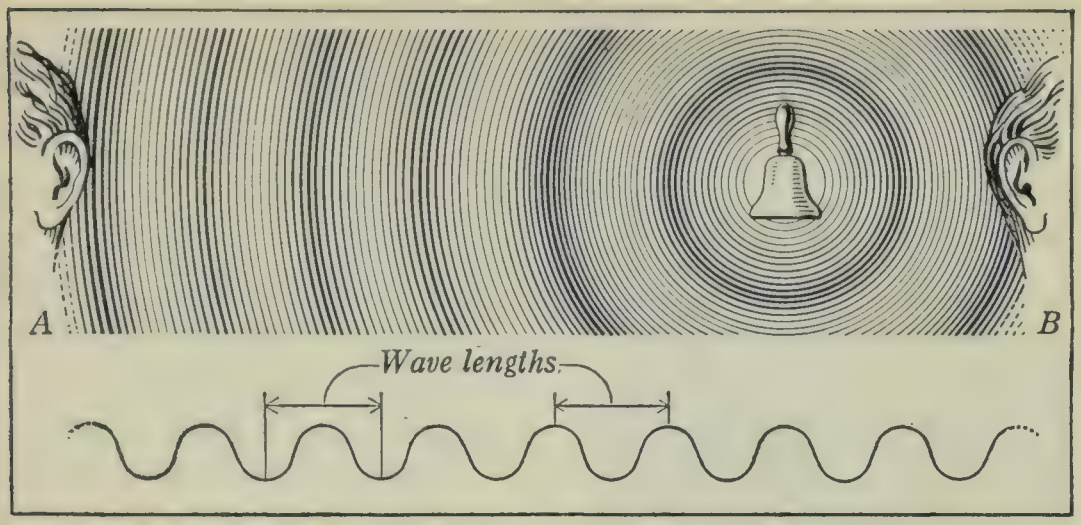

FIG. 283. Below the drawing is the diagram of the sound waves shown in the drawing. If the bell makes eighty vibrations per second, how many waves will it send out in one second? How many vibrations will reach *A* in one second? How many will reach *B*? *A* is three times as far from the bell as *B*, but the sound will be *nine* (not three) times as loud at *B* as at *A*

the surface of the water? If so, you know from experience that water carries sound very well; in fact, water transmits, or carries, sound to the ear better than does the air. Solids, such as wood and iron, transmit sound even better than water does. The energy which produces sounds is one form of kinetic energy, since sounds are carried by matter in motion.

***How sounds travel in air.** If you drop a stone into a pond, tiny waves are formed which follow each other swiftly along the surface of the water to the bank (Fig. 282). Similarly, whenever a body vibrates, it produces air waves (Fig. 283). These air waves follow one after the other away from the vibrating body in somewhat the same way as the water waves do. Since, however, sound waves travel in all directions through air, we must imagine each wave as advancing like the surface of an expanding ball.

Sounds are more readily heard at a distance if sent out directly toward the hearer. For this reason the cheer leader uses a megaphone (Fig. 284) and points it toward the people in the cheering section when he wants them to hear his directions. For the same reason speaking tubes are installed between the pilot-house and the engine room of steamships and between the front door and the various apartments in apartment houses.

Speed and loudness of sound. Have you ever seen the steam jet from a distant locomotive or factory whistle before you heard the sound of the whistle? A few moments later the sound reached you. All sounds travel at the same speed in the same substance, provided the temperature of the substance remains unchanged. At ordinary temperatures sound travels about eleven hundred feet per second in air, faster in water, and still faster in solids such as wood, metal, or stone. It travels somewhat more slowly at lower temperatures than at higher temperatures.

FIG. 284. If the people held the small ends of megaphones to their ears and pointed the large ends toward the cheer leader, they could hear the cheer leader's directions better than they could if neither the leader nor they used megaphones. Explain

*When you hear a band playing in the distance, you may at first hear only the large drum and occasional strains from some of the horns. You know that the whole band is playing, but you are too far away to hear it all. As you approach the band you hear it more plainly. You now hear some of the smaller instruments which you did not hear at first. Sounds differ from each other in loudness. The nearer you are to the vibrating body the louder the sound. Also, the more strongly an object is vibrating the louder the sound that is made (Fig. 285, *A*, *B*).

Pitch and quality of sounds. The note having the lowest pitch on a piano vibrates 27 times per second, and the highest note about 4150 times per second. The greater the number of vibrations per second the higher the pitch (Fig. 285, *A*, *C*). If a body is vibrating too fast or too slowly, however, we cannot hear it. Most people cannot hear any sounds from a body that is vibrating more than 30,000 times per second or less than 16 times per second.

Some sounds, such as the tones from musical instruments, are pleasing. Others, like Halloween noisemakers, are not. Musical tones are produced when the vibrating body sends out regular vibrations to the ear (Fig. 285, *D*). But noises are produced when the vibrating body sends out irregular vibrations to the ear (Fig. 285, *E*). If a group of people are singing together, the effect is pleasing, because the vibrations which strike the ear are regular. But if the same group begin to shout in different keys, the effect is a noise, because the vibrations which strike the ear are irregular. We know the voices of our friends. We distinguish the tones of a violin from those of the cornet or piano, even though they may be sounding the same note. These differences make up the quality of the sound. The quality may be good in the case of an expensive violin and poor in the case of a cheap one. Differences in the quality of sounds depend on the kinds of waves a sounding body gives off. A sounding body rarely gives off a single pure tone. Usually it gives off a number of tones at the same time. Thus, a violin string will give off notes of the same pitch but distinctly different in quality if it is bowed or plucked first in the middle and then near one end. The shape of an instrument and the material of which it is made affect the quality of sound which the instrument will produce, because they determine what waves will be sent off together when a note is sounded.

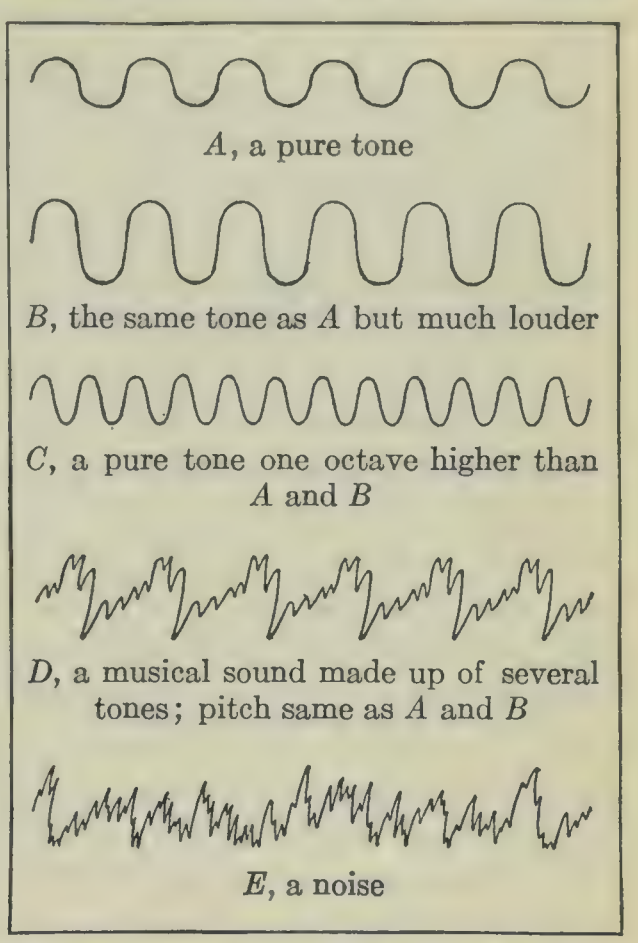
A, a pure tone
B, the same tone as A but much louder
C, a pure tone one octave higher than A and B
D, a musical sound made up of several tones; pitch same as A and B
E, a noise

FIG. 285. How do we know that *A*, *B*, and *D* are of the same pitch? How do *D* and *E* differ? If *A* has 216 vibrations per second, how many vibrations has *C*?

*Summary. Sound vibrations are a form of kinetic energy. Sounds are produced by vibrating objects. Sounds travel in matter in all directions from the sounding body. Sounds travel more rapidly at high than at low temperatures. The loudness of a sound depends both on how strongly the sounding body is vibrating and upon how far it is from the ear. Regular vibrations produce musical sounds. Irregular vibrations produce noises. The more rapidly a body is vibrating the higher its pitch. The quality of a tone depends on the nature of the vibrations sent out by the sounding body. Sounds are distinguished from each other by their loudness, their pitch, and their quality.

***What are echoes?** Have you ever made an echo by shouting toward a wall, a mountain, or a forest? The sound you made traveled to the wall, from which it was reflected back to you so that you could hear it. Such reflected sounds are called echoes. The ear is unable to distinguish between sounds which occur within less than one tenth of a second of each other. Thus sounds made in small rooms are reflected back in time to blend with the original sound. If the room is more than fifty-five feet from front to back, however, an echo is produced which interferes with the sounds being made in the front of the room. To prevent these echoes, hangings are often placed on the back wall.

***How we hear.** You have doubtless observed dogs, cats, horses, or other animals pointing the ear in the direction of a sound. You have probably seen an old person cup his hand behind his ear in order to hear better. The ears of higher animals and of people are shaped somewhat like a megaphone (Fig. 284, p. 422), that is, like a funnel with the larger end on the outside of the head. The large opening catches the kinetic energy of the sound waves and directs it toward the smaller end. Fig. 286 shows the various parts of the human ear. The sound waves strike the outer ear, which directs them against the eardrum. The sound waves set the eardrum in vibration. From the eardrum these vibrations are carried by the little bones across the middle ear to the inner ear. The sensation is then carried by a special nerve to the brain.

We really hear with our brains, because we have learned little by little, through experience, to interpret the meanings of the sounds which our ears report to our brains from our

environment. Thus our brains learn to distinguish the voices of our friends from those of strangers, though our ears report one voice as readily as any other.

*Care of the ears. Our ears are of very great importance to us as a means of getting along successfully. We need to have good hearing in order to guard ourselves against approaching dangers which we may not see, to engage in conversation with our friends, and to enjoy music. Therefore it is necessary for us to take the best possible care of our ears.

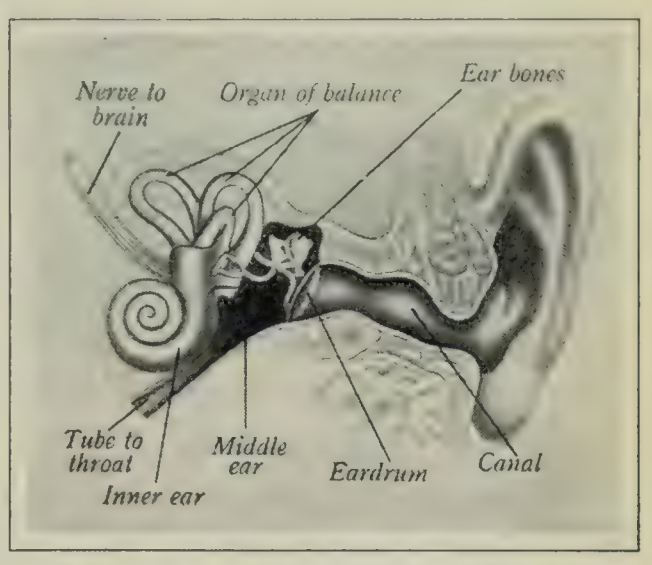

FIG. 286. If after swimming you have ever been bothered with "water in the ear," the water was in your ear canal. Can you explain how the water got into the ear canal?

*Here are some easy and sensible rules for the care of the ears:

1. Never shout directly into anybody else's ear or allow anybody to shout directly into yours. Why?

2. Never pinch your nose while you are blowing it. If you do, you are liable to cause ear trouble by blowing disease germs into the middle ear through the tube connecting the inner ear with the throat. When you blow your nose, always hold your handkerchief just under the nose, and do not pinch it until you have finished blowing it.

3. If you have trouble with your nose or throat, consult a specialist at once. It is much easier to cure such troubles if they are treated at the beginning. Nose and throat troubles sometimes cause permanent deafness.

4. Never thrust a pencil, pin, or any other sharp-pointed object into your ear. You may injure the eardrum or the lining of the canal.

Patent remedies for deafness. One can buy at most drug stores patent medicines that claim to be remedies for diseases of the ear. These state on their labels that they "relieve deafness and head noises." In certain types of magazines "eardrums" and other devices are advertised to relieve deafness. Such patent

medicines and devices neither cure ear diseases nor relieve deafness. Some of them may even do harm to the person who buys them (at a high price) with the hope of being cured. There are, however, some electrical aids which are of value to those who are partly deaf.[1] In all cases of ear trouble the only safe thing to do is to consult a physician, if possible one who is an ear specialist.

Self-test on Problem XXIV–A. (*Do not write in the book.*) **1.** If there were no vibration of matter, there could be *little* sound.

2. Sounds travel only (1) in air; (2) in ether; (3) through a vacuum; (4) in matter; (5) in liquids; (6) in solids.

3. Sounds *often* travel in waves from the vibrating body.

4. Sound waves are a form of __(?)__ energy.

5. The sound of a church bell is louder when a person is a mile away than when he is (1) a half mile away; (2) a quarter of a mile away; (3) a hundred yards away; (4) two miles away; (5) inside the church.

6. Shrill sounds travel through the air (1) much faster than sounds of low pitch; (2) at the same speed; (3) slightly more slowly; (4) much more slowly; (5) slightly faster.

7. Two sounds having the same number of vibrations per second have the same *quality.*

8. The more strongly a body is vibrating, the *higher* is the sound produced.

9. Irregular vibrations produce __(?)__.

10. One would be most likely to be able to produce echoes if he were shouting (1) in a dense forest; (2) in an open field; (3) into a barrel; (4) through a megaphone; (5) a few hundred yards from a cliff.

11. State three rules for the care of the ears.

Problem XXIV–B · How is a Knowledge of Sound Applied in Musical Instruments?

Early musical instruments. Probably the first musical instrument man used was a drum. At first this probably consisted of a stump or a log pounded with a club. Later man learned how to

[1] Some of these devices are advertised under claims that go far beyond the facts. Those who are deaf may secure reliable and practical information from the American Society for the Hard of Hearing, 1537 Thirty-fifth Street, N.W., Washington, D.C.

© Spencer & Wyckoff

FIG. 287. The National High School Orchestra. **Special Report:** What is the difference between a symphony orchestra and a philharmonic orchestra?

make better drums by stretching skins over hollow logs. Thus almost all primitive peoples have tom-toms or war drums of some sort. In our modern orchestras we have bass drums, kettledrums, and snare drums, all scientifically made and all requiring considerable skill and knowledge of music to play.

Drums can hardly be called musical instruments, since, with the exception of the kettledrum, they are used not for tones but for time, that is, the beat. When a drum is beaten, not only does the membrane of the drum vibrate but also its walls and the air confined within. Thus the sound is made louder because more matter is in vibration.

***Classes of musical instruments (Fig. 287).** Instruments which are played by being struck are called percussion instruments. Familiar percussion instruments besides drums are the piano, the xylophone, and bells. In the piano the strings are caused to vibrate by being struck with felt hammers. In the xylophone bars of wood or metal are caused to vibrate by being struck with mallets.

*Instruments which produce music when they are blown are called wind instruments. There are several different types of wind instruments. In the bugle, the cornet, the trombone, and the like the lips of the player vibrate, producing the sound. This sound is made louder by the instrument and by the air column in the instrument. With instruments such as the flute and all whistles the player blows an air jet across the mouth of the instrument, producing regular vibrations of the air column in the

instrument. With instruments like the saxophone and the clarinet a reed inside the piece for the mouth controls the vibrations.

*Instruments which produce music from vibrating strings are called stringed instruments. The violin, the cello, the guitar, and the banjo are familiar examples. The sound produced by the vibrating strings is made louder both by the wood of the body and by the air column inside the body.

Experiment 74. What conditions determine the pitch of a string? Examine any stringed instrument, such as a violin. Note the size of the different strings. Are the strings that produce the low notes bigger than those that produce the high notes? Make the strings tighter and see whether the notes produced by them are lower or higher. Make the vibrating part of the string shorter by pressing it down firmly against the finger board on the neck of the instrument. In the following principles can you select the word or phrase which makes the correct meaning?

The more tightly the string is stretched *the higher* *the lower* *the more pleasing* *the louder* *the softer* the note.

The shorter the string *the higher* *the lower* *the more pleasing* *the louder* *the softer* the note.

***The phonograph.** In 1876 Thomas Edison invented the commercial phonograph. This invention has made possible the recording and reproducing of the world's greatest music played and sung by the world's greatest musicians. In making records the music is played or sung into a receiver which has an elastic disk. This disk vibrates in harmony with the music. A needle attached to the center of the disk vibrates against a wax cylinder or plate, making a path. A copper or gold copy is made of the wax record, and from the copper or gold record, called the "master" record, many copies, or records, are made on hard rubber or other material.

*When a record is played (Fig. 288), the needle travels in the path, and is made to vibrate like the needle that cut the original path in the wax record. The vibrations from the needle are carried to a diaphragm,[1] setting it into vibration also. These vibrations set up in the air the same vibrations as those of the original music, thus reproducing the original sounds.

[1] *Diaphragm* (di'a fram): a thin vibrating disk or membrane.

The dictaphone. The modern office dictaphone is a phonograph. In using the dictaphone one dictates a letter or other material. The words are recorded on a wax cylinder just as any other record is made. At any convenient later time the typist types the material while she "plays" the record, from which the words come to her ears through earphones.

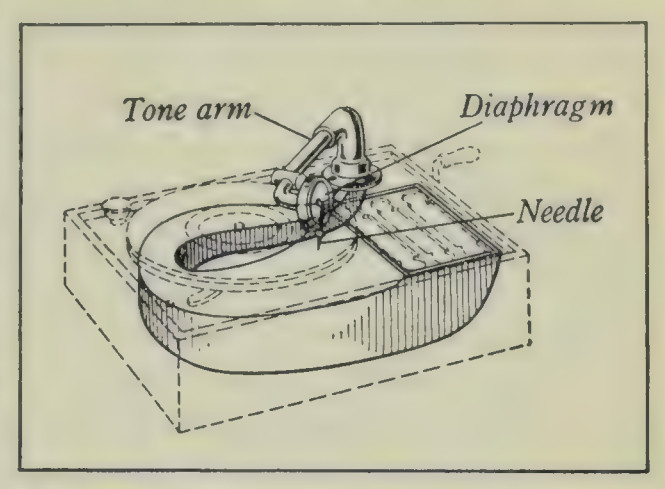

FIG. 288. Diagram of a portable phonograph. Why is the pitch of sound from a phonograph raised when the record is made to rotate faster?

***The player piano.** The player piano is made so that air pressure operates the keys. A partial vacuum is produced inside by an air pump operated by an electric motor or by one's feet. The greater pressure outside forces air through the holes in the music roll. This air current operates valves and levers, and these control the keys.

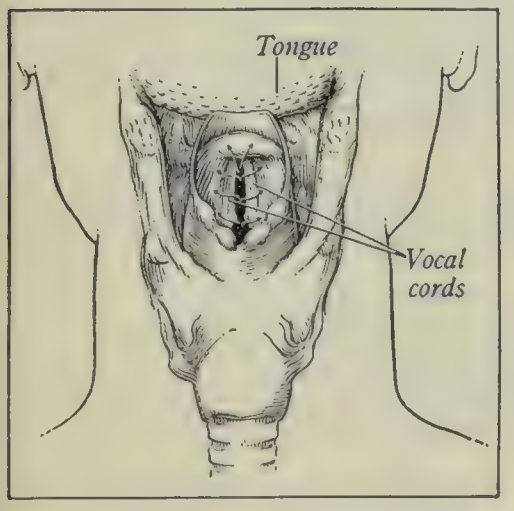

FIG. 289. Human voice-producing organ. Can you give two reasons why little children cannot sing bass? (See Experiment 74, p. 428)

***The human voice.** Differences in the quality of people's voices are due chiefly to differences in the size and shape of the air passages in the nose, mouth, and throat, and to the position and length of the vocal cords (Fig. 289). When we speak or sing we change the position of the tongue and make other changes in the size and shape of the air passages. Some have naturally pleasing voices, and others have harsh voices. Usually it is possible to improve our speaking voices by speaking in a low tone, by speaking every syllable distinctly, and by never straining the voice in speaking

or singing. Proper position of the body and good teeth are also important in good singing and speaking voices.

*The human voice-producing organ is located at the top of the windpipe in the throat, behind the "Adam's apple." When we are not speaking, the vocal cords are wide apart and air passes freely. When we speak, we close and tighten the vocal cords and the air passes from the windpipe between them in puffs. These puffs of air cause the tightly stretched vocal cords to vibrate, producing a sound. The more tightly the vocal cords are stretched and the smaller the space between them, the higher the tone. The different tones produced by the cords are made into different words and syllables by changing the positions, and consequently changing the action, of the parts of the mouth and throat.

Self-test on Problem XXIV–B. (*Do not write in the book.*) **1.** Select from the following musical instruments the one which does not belong with the rest: (1) kettledrum; (2) violin; (3) xylophone; (4) piano; (5) snare drum; (6) bass drum; (7) cymbals.

2. Select from the following musical instruments the one that does not belong with the rest: (1) bugle; (2) cornet; (3) saxophone; (4) piano; (5) trumpet; (6) tuba; (7) trombone; (8) flute; (9) whistle.

3. Select from the following musical instruments the one that does not belong with the rest: (1) violin; (2) bass viol; (3) cornet; (4) banjo; (5) mandolin; (6) ukulele; (7) guitar; (8) cello; (9) viola.

4. The vocal cords produce sounds in much the same way as sound is produced in a (1) xylophone; (2) piano; (3) ukulele; (4) bass drum; (5) saxophone.

5. In general women's vocal cords are *longer* than men's.

6. A dictaphone records the *vibrations* of the voice.

7. The vocal cords are stretched *less* tightly when a high note is sung than when a low note is *sung*.

Problem XXIV–C · How are the Telegraph and the Telephone Used in Communication?

Invention of the telegraph, the telephone, and the radio. It is seldom that the credit for any important invention belongs entirely to one man. We are accustomed to hear that Morse invented the telegraph, that Bell invented the telephone, and that

Marconi invented the wireless. These statements are not strictly true. It is true that Morse invented the first practical telegraph, Bell the first practical telephone, and Marconi the first practical radio. Every scientist who did important earlier experimenting with electricity, however, is entitled to some credit for every electrical device or machine invented later. It is not taking any credit away from the man who finally invents a practical machine to say that he has used the work of many earlier scientists as a foundation for his invention. He is entitled to great honor because he has been able to extend the work of other men. A great inventor is like a builder who is able to take a pile of material which one man has prepared, another pile of different material which another man has prepared, and so on with many different kinds of materials prepared by many different men, and, by adding materials of his own, to combine all into something new for all the world to use and enjoy.

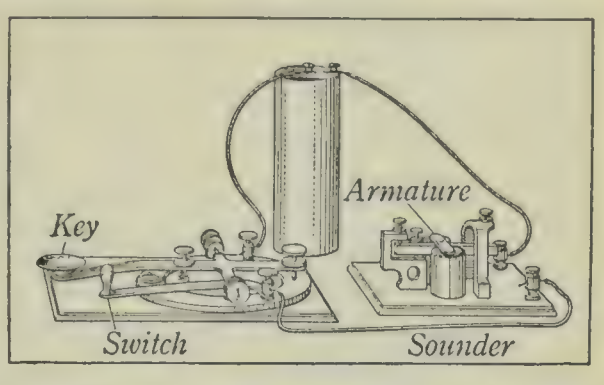

FIG. 290. A commercial telegraph key and sounder. In what respects is the action of the sounder, or armature, like the armature of an electric bell?

How the telegraph instruments operate. Fig. 290 shows a commercial telegraph sounder and key. The key acts like an ordinary switch or like the push button for a doorbell. The armature[1] of the sounder is operated by an electromagnet and a spring in much the same way as is the vibrator, or armature, of an electric bell. When the key is held down, the circuit is completed. Current then flows through the electromagnet, which attracts the iron bar on the armature, pulling it down with a sharp metallic sound. When the key is released, the spring on the key pushes the armature away from the metal frame of the key, breaking the circuit. The electromagnet at once loses its magnetism, and hence

[1] This kind of armature is not like the armature of a dynamo (see page 396). It has no coils and does not revolve, but moves back and forth or, in this case, up and down.

its attraction for the armature, which is then, by means of a spring, pulled up with a dull sound against the metal screw of the sounder.

The operator makes a dot by pushing the key down and releasing it as quickly as possible, thus first very quickly making, or completing, the circuit and then breaking it. The sharp sound made by the armature against the electromagnet is followed so quickly by the dull sound it makes against the screw of the sounder that the two sounds seem almost like one. The operator makes a dash by holding the key down an instant before releasing it. The sharp sound of the armature against the electromagnet and the duller one against the screw are heard separately. Certain combinations of dots and dashes are used to represent numbers and letters.

The telegraph system. A complete telegraph system in its simplest form is represented by Fig. 291. By grounding one wire at each station no return wire is needed, because the earth takes the place of this wire between the two stations, completing the circuit. Both keys are kept closed so that current is constantly flowing in the circuit when no messages are being sent. When the operator at *A* wishes to send a message, he opens the switch, breaking the circuit. The circuit is completed again and current will again flow through the wire only when the operator pushes down the key. The electromagnets at both ends become magnetized at the same time. When the operator at *A* finishes, he closes his switch and the operator at *B* opens his switch to reply.

A modern telegraph system. In modern commercial telegraph systems messages are not sent by hand or received by ear except in small towns. Messages are sent by typing them on a complex machine. An exactly similar machine at the receiving station types the message on paper tape as it comes over the wire. Direct-current generators at both ends of the line are used instead of batteries as the source of current. It is possible to send as many as eight different messages in opposite directions at the same time over the one telegraph wire.

***The telephone.** When we telephone to our friends we can recognize their voices. From this fact we are likely to believe that sound waves travel through telephone wires from the speaker to the listener. But if we stop to think a moment we realize that

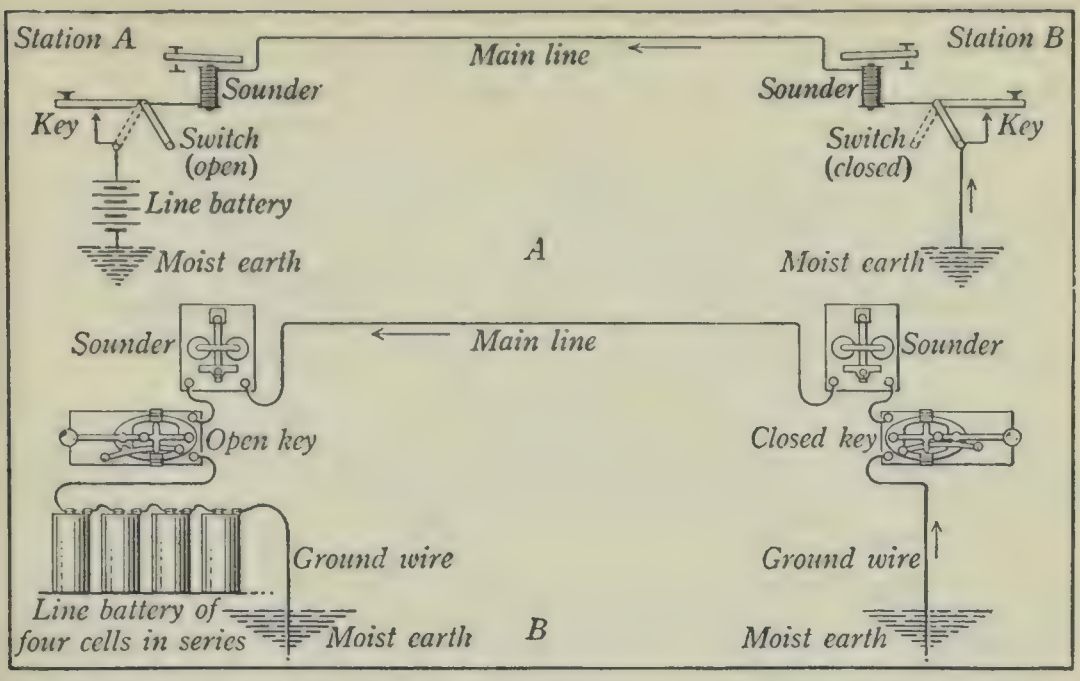

FIG. 291. *A*, diagram of a simple telegraph system; *B*, the same telegraph system with drawings of the pieces of apparatus instead of their symbols as in *A*. **Special Report:** Make a diagram of a long-distance telegraph circuit with which relays are used, and explain the action of the relay. (Consult a textbook of physics.) **Exercise on Scientific Attitudes:** We are likely to have the idea that the telegraph was invented and first used in the United States. This is not true. In 1838, six years before the first telegraph line, that between Washington, D.C., and Baltimore, Maryland, was put in operation in the United States, a practical telegraph system was in use on the London and Blackwall Railway in England. It was the invention of two Englishmen, Wheatstone and Cooke. It made use of five lines of wire and consequently was very expensive to construct and maintain. In 1839, however, after much experimenting, the partners succeeded in so improving their invention that the number of lines was reduced from five to two. In 1845, Wheatstone and Cooke improved their invention still further, so that only one wire was needed. This telegraph system, with but few changes, is still in use in smaller offices in the British Isles. Samuel F. B. Morse (1791–1872) got his first idea of inventing a telegraph while on a voyage from England to New York. He carefully worked out his plans and drawings. He then began his experimenting. In 1836 he finally succeeded in making an instrument that was fairly successful. This he improved by careful planning and further experimenting. At last he produced the practical telegraph instrument which he patented in 1837. Which of the scientific attitudes (pp. 12 and 13) are illustrated by various parts of this account of the invention and early use of the telegraph?

it would be impossible to carry on telephone conversations, especially long-distance conversations, if we had to wait for the

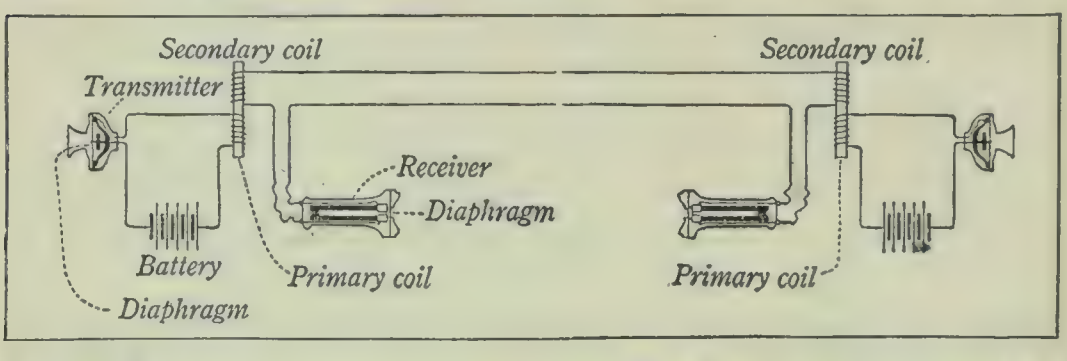

FIG. 292. Diagram of a simple telephone circuit. How many complete circuits are represented in this diagram?

sound to pass through the wires. Therefore telephone messages, like telegraph messages, are carried by currents of electricity.

A telephone circuit. Fig. 292 shows a simple telephone circuit. Fig. 293, *A*, is a diagram of a telephone transmitter, and Fig. 293, *B*, a diagram of a telephone receiver. The diaphragm of the transmitter is a thin sheet of metal. This diaphragm is attached to a small box filled with carbon granules. You will see in Fig. 292 and in Fig. 293 that the current passes from the plus pole of the battery through the carbon granules in the transmitter, thence through the primary coil, and back to the minus pole of the battery. Current is flowing through this circuit all the time.

Fig. 293, *B*, shows that the telephone receiver contains a permanent U-shaped steel magnet. On each end of this magnet is an electromagnet having many turns of fine wire wound round the iron core. These electromagnets are wound in opposite directions. The end of one next the diaphragm is therefore an *N* pole, while the end of the other next the diaphragm is an *S* pole. The circuit through the receiver is connected with the secondary coil. It will be seen in Fig. 292 that the primary and secondary electromagnets are parts of the same apparatus. Together they make up what is known as a microphone[1] transformer.

How the telephone operates. When a person speaks into the transmitter, the sound waves set up by his voice make the dia-

[1] *Microphone* (mi'kro fone): a device similar to a telephone transmitter (mouthpiece) for changing sound waves into electrical waves.

phragm of the transmitter vibrate the same number of times per second as his vocal cords. When the sound wave strikes the

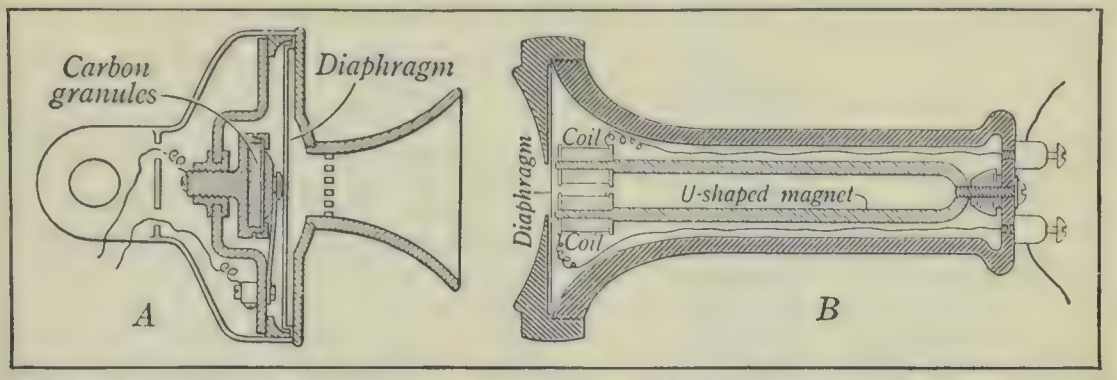

FIG. 293. Diagram of a telephone transmitter (*A*) and a telephone receiver (*B*). Can you trace the current through both these pieces of apparatus?

diaphragm, it starts the diaphragm vibrating. Each time that the diaphragm moves toward the carbon granules, it presses the granules together. The current from the battery then flows more easily through the primary circuit, because the resistance of the granules is less. When the vibrating diaphragm moves away from the granules, the granules move farther apart. The current is then weaker through the primary circuit, because the resistance of the granules is greater. The strengthening and weakening of the current through the primary circuit makes the magnetic field of force surrounding the primary electromagnet first stronger and then weaker. The changing strength of the primary electromagnet induces alternating currents in the secondary coil. Thus a current is induced in one direction in the secondary circuit when the diaphragm of the transmitter moves toward the carbon granules, and in the opposite direction when the transmitter moves away from the granules.

When these induced alternating currents pass through the receiver at the other end of the secondary circuit, the electromagnets on the ends of the permanent magnet in the receiver are magnetized first in one direction and then in the other. These electromagnets therefore strengthen and weaken the field of force surrounding the permanent magnet. This changing magnetic field sets the diaphragm of the receiver vibrating in time with the diaphragm of the transmitter. The diaphragm of the receiver therefore sets up sound waves like those of the voice in the transmitter.

The modern long-distance telephone lines consist of four wires. It is possible to send over these both telephone and telegraph messages. Thus it is possible to send as many as fifteen telephone messages and seventy-two telegraph messages over the same wires at the same time.

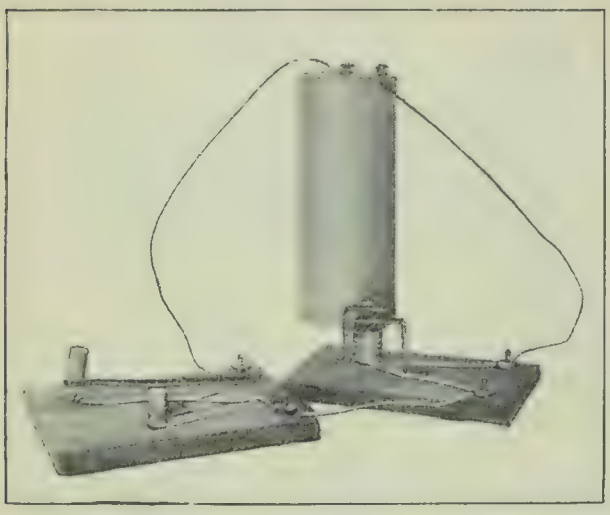

FIG. 294. A home-made telegraph key and sounder. **Special Report:** The invention of the telegraph by Samuel F. B. Morse. (Consult an encyclopedia)

Self-test on Problem XXIV–C. (*Do not write in the book.*) 1. It would be *possible* to make a satisfactory armature for a telegraph sounder from brass.

2. The *armature* of a telegraph sounder completes and also breaks the circuit through the electromagnet.

3. The electrical energy used in most telegraph systems is furnished by *dry cells.*

4. The *coil* in a telegraph sounder becomes a magnet when the key is pressed down.

5. The electromagnets in a telephone receiver are wound in *opposite* directions in order that their end poles may be *alike.*

6. The telephone is made to operate by *steady* currents of electricity through both the transmitter and the receiver.

Self-test on Scientific Principles. How would you explain the following principles to a pupil of your own age who had not studied science?

Sounds travel only through matter.
Sounds are produced by vibrating bodies.
Sounds travel in waves.
The more rapidly a body vibrates the higher is its pitch.

Can you find and explain any other principles from this chapter?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Walls which are filled with loose sawdust or which have air spaces between them are good "deadeners" of sound. Why?

2. If you were to see a flash of lightning a mile away, about how many seconds should you have to wait before you would hear the thunder?

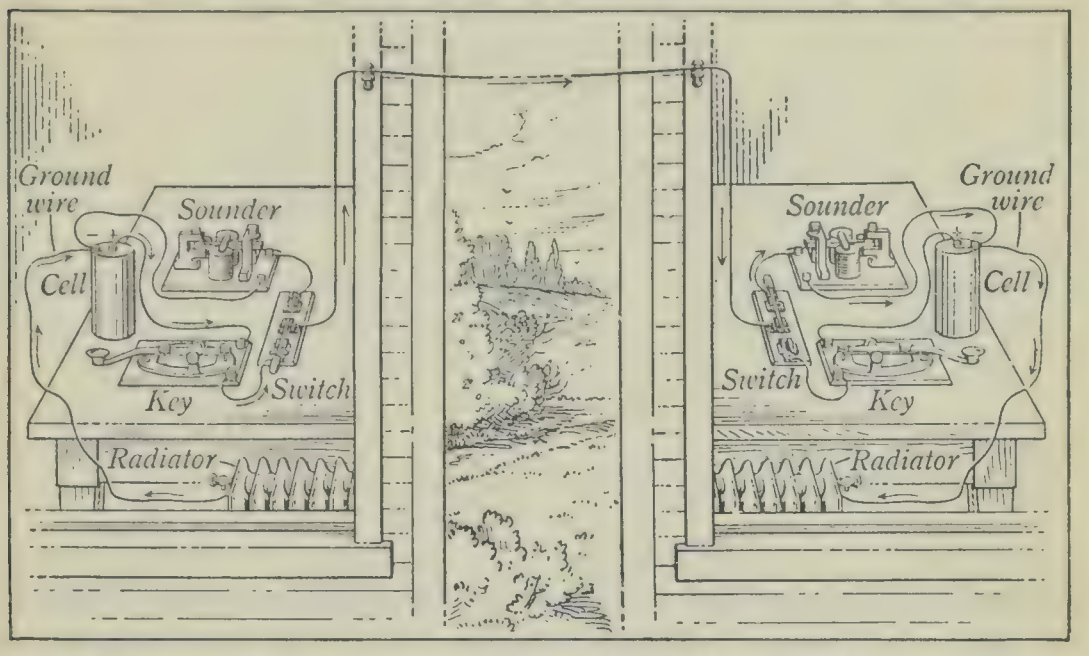

FIG. 295. Connect the apparatus as indicated here. If you need to use more than one dry cell at each end, use an equal number at both stations. Use insulated copper wire No. 18 or No. 22. **Special Report:** Elisha Gray's invention of the telephone. (Consult a history of science)

3. Why could the Indians and the pioneers find whether horses were approaching by placing their ears to the ground?

4. About how many miles per minute does sound travel?

5. When machinery is first started, the sound is at a lower pitch than after the machinery is going at full speed. Why?

6. Why is the sound of the wings of a flying bird so much lower in pitch than that of a flying insect such as a fly or a mosquito?

7. In which of the three big classes of instruments would you place the jew's-harp?

8. What would happen if the operator at either end of a telegraph system forgot to close his switch when he finished sending?

9. Why are echoes never produced within about fifty-five feet of the reflecting surface? (Remember how far sound travels in one second.)

Exercise on Scientific Attitudes. Which of the five statements that follow this problem would a carefully trained scientist choose as the best? Select one or more of the scientific attitudes (pp. 12 and 13) to justify your answer.

A man happens to wake in the night just as the clock is striking three. He immediately goes to sleep again. Though he is usually a sound sleeper, he wakes again the next night at exactly the same hour. He thinks little of the incident, but the third night he wakes again as the clock is striking three and hears somebody trying to break into the house. The man concludes that in some way his waking on the *two* preceding nights at *exactly* the same hour that the robber tried to enter was a communication of warning, or at least that it had some connection with the robber's attempt.

a. The man's conclusion is sound, without doubt.

b. It is extremely unlikely that the conclusion is sound.

c. It is unlikely that the conclusion is sound.

d. The conclusion is probably sound, for very strange things happen sometimes.

e. It is possible that the conclusion is sound.

Projects. 1. To make a simple telegraph key and sounder. A boy who was studying general science made the instruments shown in Fig. 294, with wire, screws, and strips of iron. The armature of the sounder is flexible (easily bent).

2. To make a "home and home" telegraph system (Fig. 295).

Special Reports. 1. Describe the Wurlitzer or the Barton organ; the pipe organ.

2. Diagram a long-distance telegraph circuit with which relays are used. Explain the action of relays.

3. Describe a carillon and explain how the bells are played. Describe also how and of what materials the bells are cast.

4. Describe and classify several unusual musical instruments, such as the vibrophone, the marimba, the dolceola, and the ocarina.

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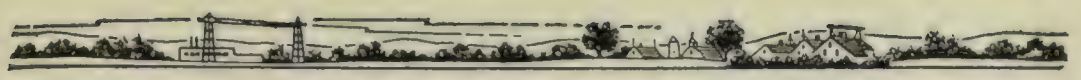


Chapter XXV · Radio and Television in Communication[1]

Questions this Chapter Answers

What are the principles of radio?
What are the elements of a system of radio communication?
How are radio waves transmitted?
How are radio waves received?
How is television accomplished?

Problem XXV–A · How is Communication Effected through Radio?

Early progress in radio. One can understand the principles and practices of radio transmission[2] and reception[3] only through a study of electricity and its applications in radio engineering. Modern radio has resulted from developing certain earlier discoveries. In 1865 Clerk Maxwell, an English scientist, concluded from reasoning, but without experimenting, that all forms of electromagnetic energy were similar to light energy. He suggested that any form of radiant energy, — that is, light energy, radiant heat, and electromagnetic energy, — could be sent through space in the form of waves. Twenty years later Heinrich Hertz succeeded in proving by means of experiments the truth of Maxwell's conclusion. He discovered that when he produced a strong spark, another spark would jump across a small gap between the ends of a coil of wire placed some distance away. He improved his apparatus and demonstrated beyond doubt that electromagnetic energy travels from the spark coil (sending set) to the other coil (receiving set) with the velocity of light (about 186,000 miles per second).

[1] To the Teacher. In many cases it will not be found desirable to require mastery of this chapter. Pupils especially interested in radio can master all the chapter, and some will also perform the radio projects outlined in Chapter XXXVIII.

[2] *Transmission* (trans mis'shun): act of sending.

[3] *Reception* (re sep'shun): act of receiving.

Oscillating discharges. You will recall that in an alternating current the electrons which compose the current travel first in

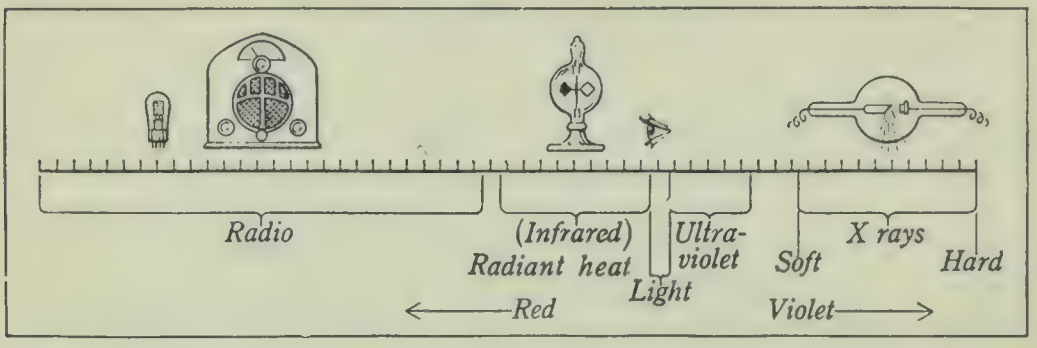


FIG. 296. A chart of the ether waves. The longest waves of radiant energy are radio waves; the shortest are X rays. How many times as great as the range of light waves is the range of radio waves?

one direction along the conductor and then in the other. These exceedingly rapid changes in movement of the electrons are alternations, or oscillations.[1] Other illustrations of oscillations are perhaps more familiar. A swinging body, like a clock pendulum, oscillates. Floating objects, as corks or pieces of wood, move up and down, or oscillate, on water waves. Electromagnetic, or radio, waves are likewise oscillations. Oscillatory, or oscillating, electromagnetic waves are often produced by lightning discharges, electric arcs, and electric appliances. Like sound waves, water waves, and all other kinds of waves, a radio wave length is measured from a given point in the wave to the corresponding point in the next wave. To state this in another way, the wave length is the distance that the wave travels during one vibration, or oscillation. The number of vibrations, or oscillations, per second is called the frequency. The distance that a wave length travels in one second is called the velocity. The velocity of all electromagnetic waves, including radiant heat waves, light waves, and radio waves, is about 186,000 miles per second, or about 300,000 kilometers per second. For all practical purposes we can express the velocity (distance traveled per second) as the product of the wave length (distance traveled during one vibration) and the frequency (number of vibrations per second).

[1] *Oscillate* (os'il ate): to vibrate or swing back and forth. *Oscillation* (os il a'shun): a swing of an oscillating body.

Wave lengths and kilocycles. It is common to speak of the frequency as the number of kilocycles[1] per second, of the velocity as the number of meters per second, and to express the wave length in meters. The frequencies used in commercial radio communication range from 12 to 30,000 kilocycles. For example, the broadcasting station WABC of New York has a frequency of 860 kilocycles, and since the velocity of all electromagnetic waves is approximately 300,000,000 meters per second, the wave length is the velocity divided by the frequency, or 349 meters. Radio wave lengths vary, however, from several miles to a few feet (Fig. 296).

Elements of a system of radio communication. There are two parts involved in a radio system, a sending set and a receiving set. The function of the sending set, or transmitter, is both to generate and to control radio-frequency waves, that is, oscillating electromagnetic waves.

The spark coil was the earliest and for many years the only method available for the generating of radio-frequency waves. It was unsatisfactory, however, because it could not be made to generate a single frequency. As a result, radio signals from one set interfered with those transmitted by others. With the invention of the vacuum tube, however, it became possible to produce electromagnetic waves which were of unchanging frequency and unchanging strength. Thus while the spark coil had produced at the same instant waves of many frequencies and strengths (somewhat like a noise composed of many pure tones), the vacuum tube used as an oscillator, or transmitter, produced a single pure wave (somewhat like a pure tone which remains of unchanging loudness).

Transmission of information by radio waves. In wireless telegraphy messages are sent in the dots and dashes of a telegraph code. A dot is formed when the transmitter is allowed to emit, or send out, its unchanging electromagnetic waves for a very short time. The dash is formed when the waves are emitted, or sent out, for three times as long a time as for a dot. A telegraph key is used to control the sending of the dots and dashes.

[1] *Kilocycle* (kil'o si kl): one thousand cycles, or vibrations.

Changing sound waves into radio waves. In the ordinary broadcasting of voice or music the oscillator is permitted to set up its continuous unchanging pure waves (called carrier waves). These waves are changed by a second device of vacuum tubes (called a modulator[1]). This device serves to combine the waves from the oscillator with the waves from the voice or music after the ordinary sound waves have been changed by a microphone into electrical waves. These changed, or modulated, waves are sent out as electromagnetic waves from the broadcasting station.

Self-test on Problem XXV-A. (*Do not write in the book.*) **1.** The earliest experiments with radio were those of *Maxwell.*

2. Radio waves are produced by *D.C.*

3. The number of kilocycles per second depends upon the __(?)__ in meters per second and the __(?)__ in meters.

4. The vacuum tube is an *unimportant* part of the modern radio.

5. Radio waves are a form of *energy.*

Problem XXV–B · How are Radio Messages Sent and Received?

The vacuum tube. The vacuum tube was developed from the electric lamp. The earlier type of vacuum tube had only two parts. These were a filament or wire similar to that of an electric lamp, and in addition a metal plate. Radio broadcasting was practically impossible, however, until in 1907 Lee De Forest added a grid to the two-element vacuum tube. Progress has been rapid since then. The filament is made from a special wire that will easily give off electrons when heated to the proper temperature by an electric current. The plate is a flat or cylinder-shaped sheet of metal charged positively by being connected to the positive side of a battery or to the positive side of some source of electrical power. As unlike electrical charges attract each other, there is a steady flow of electrons across the gap from the hot filament to the plate.

[1] *Modulator* (mod'yu la tor): a device for changing the strength of an electromagnetic wave.

Fig. 297 shows the essential parts of a two-electrode vacuum tube and the way in which the tube is used to produce a current in the plate circuit. The *A* battery (usually 1.5 to 6.3 volts) is connected to make a complete circuit with the filament of the vacuum tube. When passing through the filament of the tube, the current from the *A* battery heats up the filament to a temperature at which electrons are easily given off, or emitted. The circuit of the *B* battery (called plate circuit) is complete except for the small gap between the filament and the plate. The plate has a positive electrical charge because it is connected to the positive pole of the *B* battery. This positive charge on the plate attracts the electrons (negatively charged particles), causing them to travel across the gap between the filament and the plate. These electrons then travel along the wire, through the *B* battery and back to the hot filament, completing the circuit. This continuous flow of electrons through the circuit can be detected by means of a milliammeter [1] connected in series in the plate circuit. De Forest discovered that this flow of electrons from the filament to the plate could be varied by the addition of a third part to the tube. This part, called the grid, is an electrode made from fine wire.

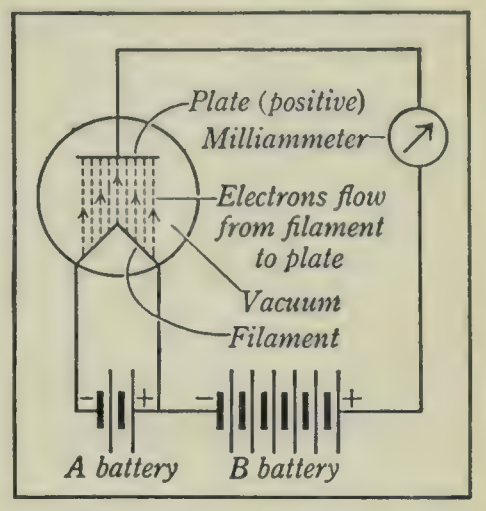


Fig. 297. Diagram showing the operation of a two-electrode or two-element vacuum tube. Will a current flow when the *B* battery is connected in the way opposite to that shown here, that is, with its negative terminal connected to the milliammeter and through it to the plate of the vacuum tube? Explain

Fig. 298 shows the essential parts of a three-element tube. The tube is the same as the two-electrode tube except that the grid has been placed in the space between the filament and the plate. In addition to the *A* and *B* batteries used with the two-element tube, a third source of electrical pressure, or potential,

[1] *Milliammeter* (mil e am'me ter): an electrical meter for measuring small electrical currents.

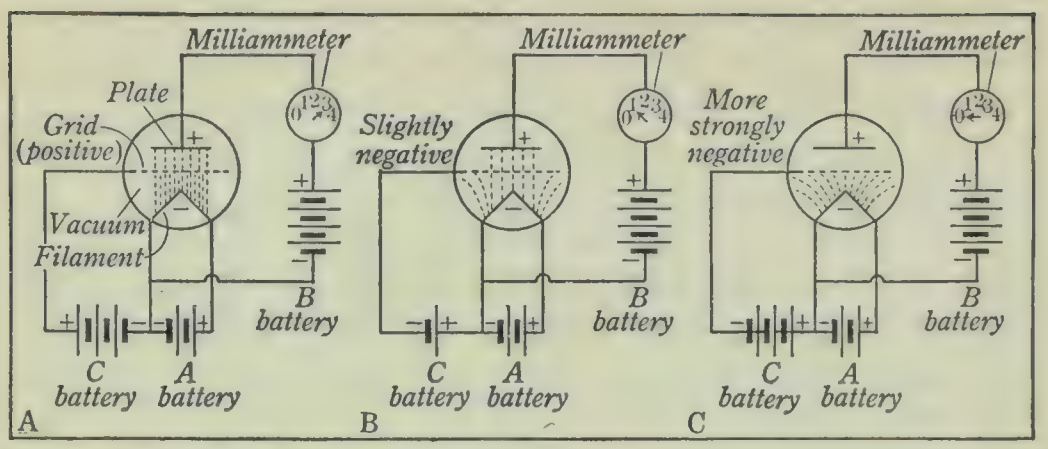


FIG. 298. The effects of positive and negative grid charges on the current in a three-element vacuum tube. What is the effect of a varying charge on the grid upon the number of electrons that pass from the filament to the plate?

the *C* battery, must be used so that the grid has some definite charge. The figure shows the grid connected to the positive end of the *C* battery. This arrangement gives the grid a positive charge and so helps attract the electrons from the hot filament across the gap. The electrons pass through the open mesh of the grid and are carried to the plate by the greater positive charge on the plate. When the *C* battery is connected with its negative end to the grid, the resulting negative charge on the grid prevents to some extent the flow of the electrons across the gap. As a result the plate current is not so great as it is when the grid is given a positive charge.

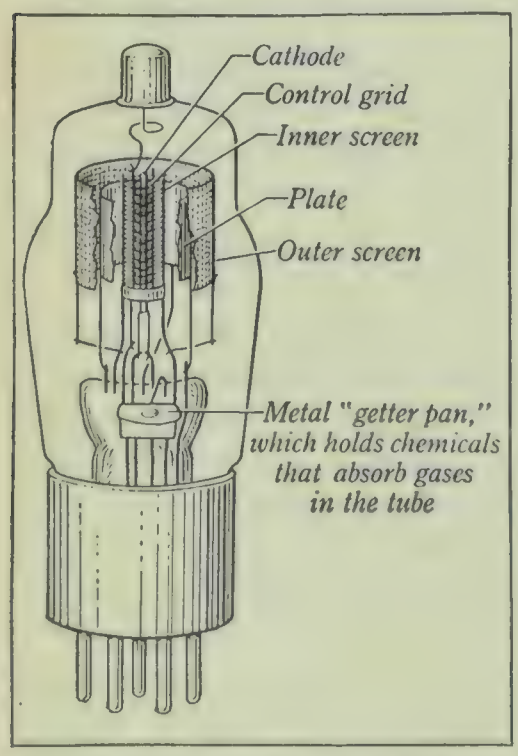


FIG. 299. Sectional diagram of a screen-grid tube. The outer screen and plate have been partly removed to show the inner screen and control grid. What parts does this tube have that earlier types of tubes did not?

The grid may be charged either negatively or positively. In actual practice the charge on the grid (the potential of the grid) is constantly being varied.

A very weak changing electrical charge on the grid may modify a much larger plate current by affecting the flow of electrons from the hot filament to the plate. Modern radios often use more than three elements in the tubes. The most common modern tube has an additional element called the screen grid (Fig. 299).

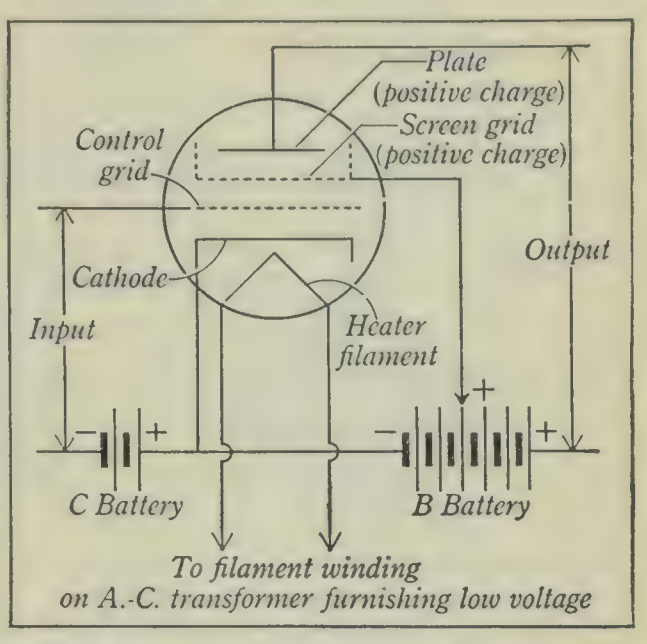


FIG. 300. Diagram of the circuit used for a screen-grid vacuum tube. Which battery used with a simpler vacuum-tube circuit (Fig. 297) is not used here? What is used in its place? Explain

The introduction of a so-called screen grid that is also charged positively permits the vacuum tube to increase still further the strength of the plate current and thereby to amplify, or increase, the volume of the radio signals (Fig. 300). The plate strength is further modified or amplified by the relative positions of the elements in the tube. Also the electrons are emitted from a cathode, or negatively charged electrode, which is heated indirectly by the heater filament. The heater filament heats the cathode to a temperature at which the electrons are given off freely from the cathode.

The introduction of the cathode in a vacuum tube makes it possible to use alternating current directly upon the heater filament. If the cathode were not used, a "hum" would be produced in the tube by the modulating effect of the magnetic field that accompanies the heater current.

The broadcasting station. The apparatus used in radio broadcasting stations is so complicated that one cannot possibly understand the details of operation without years of special study. However, it is possible to understand the general principles without attempting to learn the various details of the construction of the set used or the functions of all the various parts in the circuits. Fig. 301 illustrates the various parts of a sending station

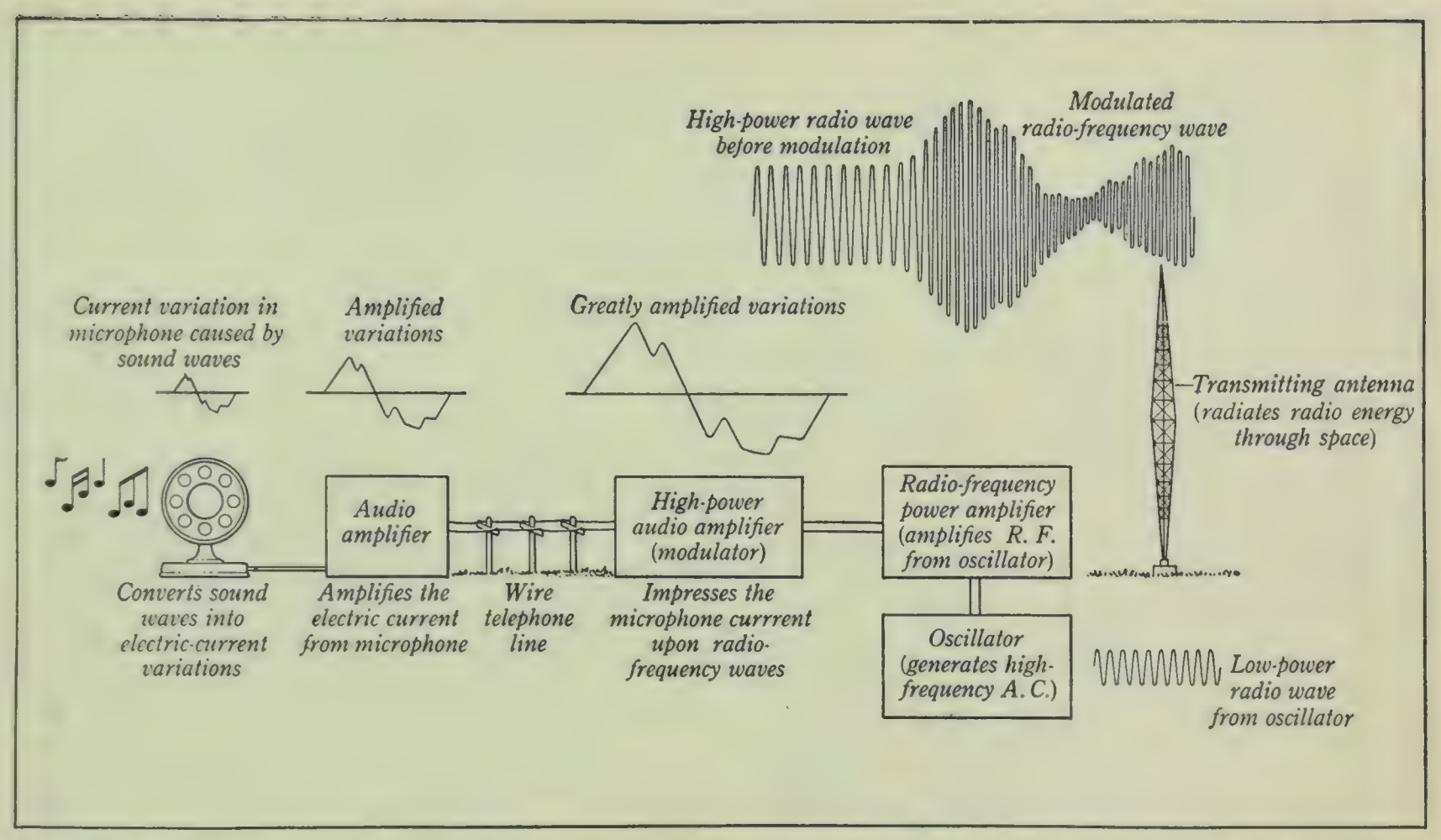

High-power radio wave before modulation
Modulated radio-frequency wave
Current variation in microphone caused by sound waves
Amplified variations
Greatly amplified variations
Transmitting antenna (radiates radio energy through space)
Audio amplifier
High-power audio amplifier (modulator)
Radio-frequency power amplifier (amplifies R. F. from oscillator)
Converts sound waves into electric-current variations
Amplifies the electric current from microphone
Wire telephone line
Impresses the microphone currrent upon radio-frequency waves
Oscillator (generates high-frequency A. C.)
Low-power radio wave from oscillator

FIG. 301. The essential elements of a radio broadcasting station. After reading the text, can you explain this diagram?

and how these parts are related to each other. The essential parts of such a system are a microphone, an audio-frequency[1] amplifier,[2] an oscillator, a modulator, a radio-frequency[3] amplifier, and an antenna, or aerial. The microphone is somewhat similar in its construction and use to a telephone transmitter; in fact, the first microphones used in radio broadcasting were telephone transmitters. The microphone serves to "pick up" the sound waves of voice and music and transform the sound waves into electrical currents. These are direct currents of varying intensity, or strength. The audio-frequency amplifier is a device consisting of a system of vacuum tubes, condensers,[4] and transformers which serves to increase the strength of the varying direct current from the microphone. The oscillator consists of vacuum tubes, coils, and condensers. It serves to generate an alternating current of very high frequency (radio-frequency) and of uniform strength. The modulator is a vacuum tube which produces a current of radio-frequency alternations of varying strengths. This it does by combining the varying direct current produced by the microphone circuit and the audio-frequency amplifier with the radio-frequency alternations from the oscillator. The production of these "modulated" radio-frequency alternations can be accomplished by connecting the plate circuit of the audio-frequency amplifier to the grid of a three-electrode vacuum tube used as the modulator. The varying direct current from the audio-frequency amplifier causes a varying electrical charge on the grid, and this varying grid potential regulates the flow of electrons from the filament to the plate and produces the modulated radio-frequency alternations. A second and perhaps more important method of producing the modulations is to vary the high-frequency alternating plate current by adding the audio-frequency, or voice, current directly to the plate current. Other methods of varying the high-frequency current (modulation) are sometimes used.

[1] *Audio-frequency:* having to do with frequencies which can be heard by the human ear.

[2] *Amplifier* (am'pli fi er): a device for increasing the strength of vibrations.

[3] *Radio-frequency:* having to do with frequencies which are too rapid to be heard by the human ear.

[4] *Condenser* (kon dens'er): an electrical device used for storing electrical charges, or electrons.

After the establishment of the modulated high-frequency alternations, they are amplified, or made stronger, by a radio-frequency amplifier. They are then carried to the antenna, or aerial, where they produce electromagnetic waves, which are the radio waves sent out "on the air" by the broadcasting station.

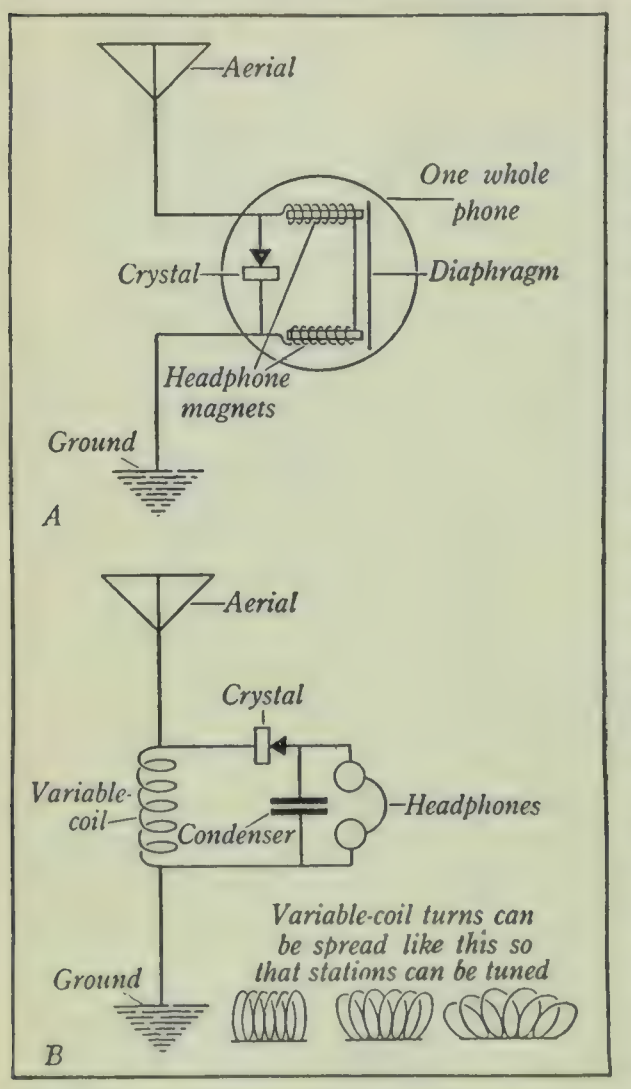


FIG. 302. *A*, diagram of a simple crystal set built in a headphone unit. Why is the set grounded? *B*, diagram of an easily constructed crystal set

The receiving set. The purpose of a receiving set is that of receiving the radio energy from the air, selecting the desired wave length from the many available, changing the alternating current to pulsating[1] direct current, and amplifying the pulsating direct current so that it will operate the speaker. The simpler sets usually will operate only near a powerful station and need no tuning device. One very simple set consists of only an aerial, a ground, and one phone across the magnets of which a crystal of galena is attached (Fig. 302). The crystal is firmly attached to one wire. The other wire completes the circuit by resting on the crystal. The wire point (called the "cat's whisker") is moved about on the crystal until a spot is found where the sounds are heard most clearly.

Another simple receiving set consists of an antenna, a coil, a crystal, a condenser, and a pair of phones (Fig. 302, *B*). This

[1] *Pulsate* (puls'ate): to flow irregularly like a pulse.

quickly assembled set may readily be tuned by varying the spread of the coil of wire with the hand until the desired station is heard.

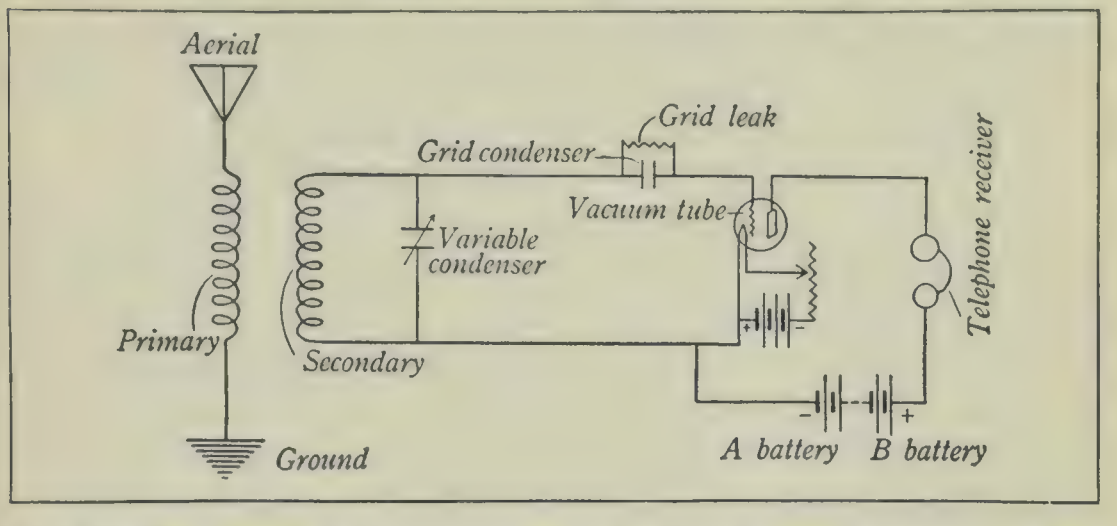


FIG. 303. Diagram of a one-tube receiving set. Can you name some other electrical appliance besides a radio set in which an A.C. in a primary coil induces an A.C. in a secondary coil?

Radio receiving sets of the type shown in Fig. 302 are now considered as toys. Instruments employing one or more tubes and receiving either long or short waves are now employed. Fig. 303 shows the relations of the various parts of a simple one-tube set. The operation of such a set is fairly simple. The oscillating high-frequency waves from the broadcasting station are received by the aerial, or primary circuit. If the set is properly adjusted, or "tuned," the current surging back and forth in the primary circuit induces a like current in the secondary circuit. This current, too, is essentially like the current of the broadcasting station. It will be observed that the control grid of the tube is connected in the secondary circuit in such a way that, as the electrons of the current oscillate, it has alternately a large and a very small number of electrons; that is, the strength of the negative charge varies. As you observed in Fig. 298, this changing of charge on the grid prevents or helps the flow of electrons from the filament to the plate, thereby producing a pulsating current in the plate, or phone, circuit. This pulsating current causes the diaphragm of the phone to vibrate much as does the diaphragm in a telephone receiver (Fig. 293, p. 435) with the result that vibrations are produced in the air which are very

much like those received by the microphone at the broadcasting station. Most home receiving sets, however, must provide loud-speaker performance. Therefore the oscillating current is amplified by added coils, condensers, and tubes before being detected, and the pulsating current is also amplified by added transformers or resistances and tubes before reaching the loud-speaker.

The short-wave set. The various short-wave sets are built to operate on frequencies which will produce electromagnetic waves from a very few feet in length to waves whose length is about six hundred feet. Certain ranges (or bands) are set aside by the Federal or the Dominion government for use by amateur operators, while other bands are reserved for police broadcasts, commercial airway communication, broadcasts from ships, and broadcasts for various other commercial uses. There are seven definite bands reserved for the use of the amateur. The wave lengths of these bands center about 2.5 meters, 5 meters, 10 meters, 20 meters, 40 meters, 80 meters, and 160 meters. Certain of these bands are limited to code communication, while other bands may be used for both code and phone communication. The strength, or power, output of these short-wave stations is definitely limited by the government to a maximum of 1000 watts. Remarkable distances are covered by the short-wave sets, although the power output of them is small when compared with the power output of the regular broadcasting stations.

Fundamentally, the short-wave sets do not differ from the regular broadcast transmitters and receivers except in the size of the condensers and coils used in tuning.

Self-test on Problem XXV–B. (*Do not write in the book.*) **1.** Radio waves may be produced by a changing flow of *protons* through a vacuum tube.

2. The modern four-element vacuum tube has a filament, a __(?)__, a __(?)__, and a __(?)__.

3. The *heater filament* is used to prevent "hum" in the vacuum tube.

4. What purpose is served by the oscillator, the modulator, and the amplifier?

5. Sound waves are changed to radio waves in the *receiver*, and radio waves are changed to sound waves in the *transmitter*.

Problem XXV–C · How is Television Accomplished?

What is television? Television involves the transmission of a picture as well as the transmission of sound. The receiving

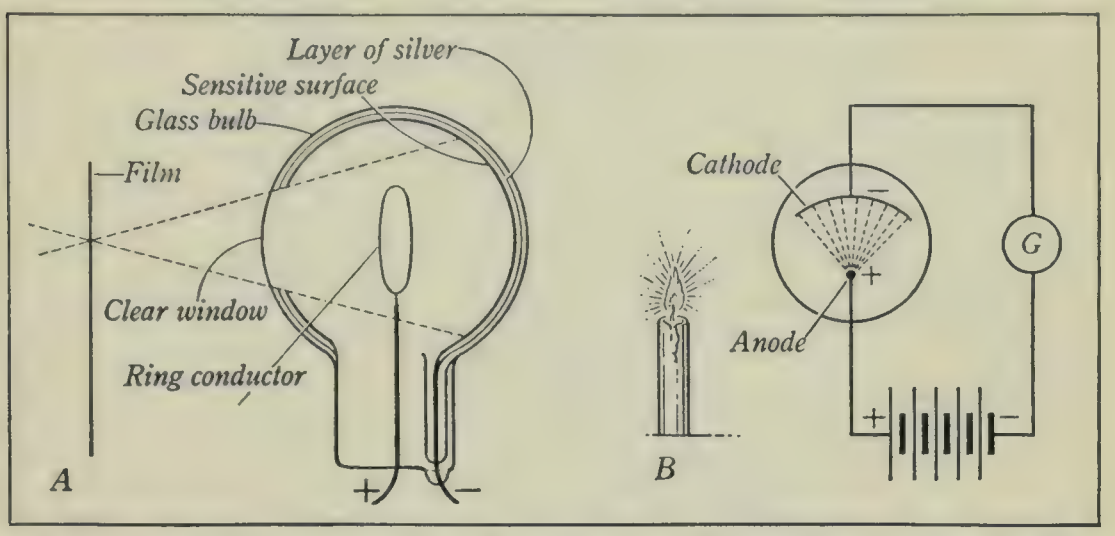


FIG. 304. *A*, a photoelectric cell; *B*, diagram of photoelectric cell. When light strikes the cathode, electrons are given off and travel to the anode, producing a current that can be measured by the galvanometer. As the light becomes more intense, more current is produced. Why?

operator in television sees the speaker, actor, or singer and also hears him. Thus television may be called sound radio plus light radio. Many problems relating to television are not yet solved, but large advances have been made in recent years.

In order to transmit an image by radio some means of changing light values, that is, shadows and bright places, into electrical impulses of varying amplitude had to be devised. To receive images, it was necessary to change electrical energy back to light values. At the same time, a means for distributing the light and dark portion of the picture in such a way as to reconstruct the transmitted picture had to be developed.

How is energy used in television? How light energy is transformed to electrical energy by the use of a phototube or photoelectric cell (Fig. 304) is explained thus: The clean surfaces of most metals give off electrons whenever light strikes them. Therefore, if two metal electrodes, a plate and a rod, in a vacuum tube are connected to each other as in Fig. 304, *B*, a current of electrons is caused to flow through the circuit whenever light falls

upon the metal plate. If the light is properly adjusted, the number of electrons given off by the plate becomes greater or less as the

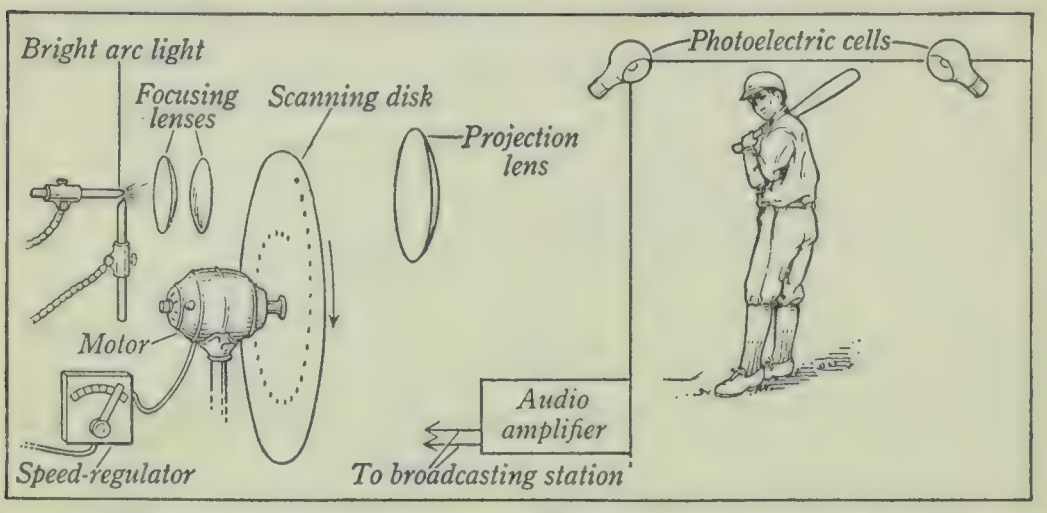


FIG. 305. The usual method of scanning. Why is it better to have the light than the photoelectric cell behind the disk?

light that strikes it becomes more or less intense. Thus a current of varying strength is produced in the tube, or photoelectric cell.

A face or a photograph possesses some parts that are quite dark and others that are very light. As a matter of fact, the appearance of an object depends on the reflection of light from a large number of separate points.

What is the picture that is seen? In television, if a representation of a human face is to be sent by wireless, a disk, called a scanning disk, filled with many tiny holes, often square and sometimes filled with tiny lenses, is revolved in front of the face. These holes are arranged in the form of a spiral. Sometimes rotating prisms are used to secure the same effect. Behind this disk is a powerful light source of uniform strength which focuses upon the face a pencil of light, called "flying spot," through the holes in the disk. The spiral arrangement of the tiny holes causes each passage of the spot across the face to take a different path. Several properly placed photoelectric cells receive the light reflected by the face. As the spot of light travels over alternating light and dark portions of the face, the intensity of the light reflected to the photoelectric cells varies. This variation produces changing currents of electrons in the cells (Fig. 305).

Actually the face is not a face any longer, but is a large number

of light and shadow spots arranged in a series of horizontal lines. It is obvious that a number of points or spots large enough to give the impression of a complete face must be taken. It is also clear that each point must be repeated often enough to make the face or picture appear continuous and not changing. The device must be operated at a speed that will allow the "flying spot" to hit the same point on the face at least twenty times a second. Experiments with motion pictures indicate that twenty-four pictures per second are necessary to get a motion that does not tire the eye.

For purposes of illustration let us suppose that a square picture is being transmitted. Let us suppose, also, that each horizontal line is composed of 100 points of different light values. Since the picture is square, there will be 100 lines, each containing 100 parts, or a total of 10,000 points in the whole picture. To give the feeling of continuous vision each point must be repeated at least 20 times per second. This makes the total number of reflections to be received by the photoelectric cells 200,000 per second. Since experiments have shown that the minimum number of lines acceptable for transmission is 180, it is evident that there would be an enormous number of points reflected each second.

How is the picture broadcasted? Each part of the face or other object reflects a quantity of light depending upon its whiteness to the one or more phototubes described. As different parts of the face reflect different amounts of light, the quantity of light received by the phototubes, and also the tiny currents generated by them, vary. These varying currents are amplified and broadcasted in a manner very similar to the broadcasting of the currents produced by sound.

The aerial at the receiving station picks up the electromagnetic waves, which are changed into a varying, or pulsating, electrical current and amplified by a vacuum-tube set similar to the sets used for music and speeches. The amplified pulsing current, however, instead of going to a loud-speaker, goes usually to a neon tube located behind a reproducing disk similar to the scanning disk at the transmitter. The sensitive neon tube gives out little flashes of light that vary in brightness just as the points on the face varied in brightness. Now if the reproducing disk is revolved at exactly the same speed as the transmitting disk,

the face is built up from these points of light upon a tiny screen made of ground glass (Fig. 306). Some receiving sets and transmitters use cathode-ray tubes to escape the mechanical difficulties of scanning and reproducing. In these receivers a small beam of electrons plays about on a ground-glass screen, producing the same effect as the disk.

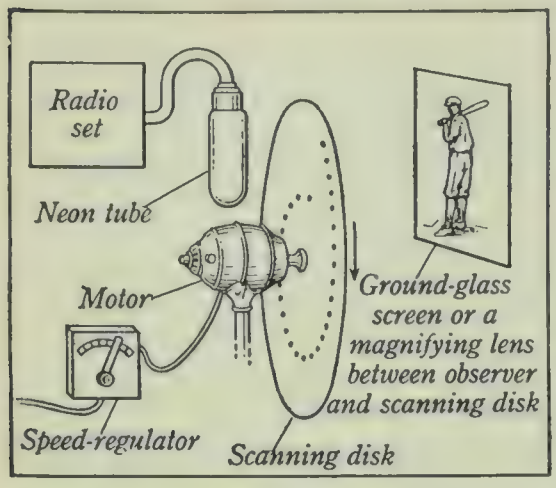


FIG. 306. Diagram of a simple television receiver. From a reading of the text can you explain this diagram?

Although television is not generally used, there are already a number of transmitting stations in the United States. Many of these use independent systems of transmitting. One of the difficulties in television is that one receiver will not readily serve with all the stations. Television is still in the experimental stage of development, and uniform methods of transmitting will have to be agreed upon before it will be commercially successful. Another difficulty is that the present method of scanning does not allow large scenes to be broadcasted. Also, the effect of static seems greater in television than in radio broadcasting.

Pictures by wire. Newspapers and the Department of Justice often find it desirable and necessary to have a picture quickly transmitted from one part of the country to another. Although several mechanical devices have been perfected and used for the transmitting of pictures by wire, the most effective method employs the "flying spot" method described for television. Wirephoto has several advantages over television for commercial purposes. The network is privately owned. Many mechanical and technical difficulties are eliminated. The picture can be reassembled more leisurely, because clear vision is not necessary. The danger of double images, always associated with broadcasting pictures, is eliminated. It seems, at present, to be the most desirable method of transmitting pictures for newspapers and for similar purposes.

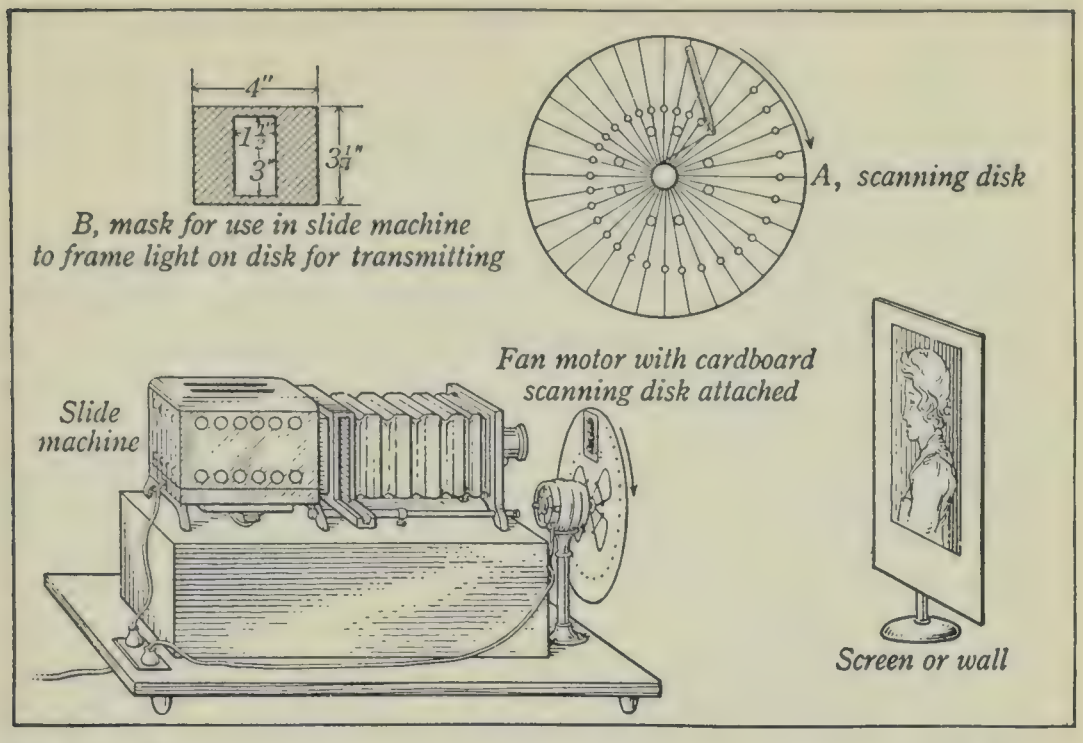


FIG. 307. How television may be demonstrated in the classroom. The diagram illustrates the way in which an image is received by television. To show how an image is scanned remove the slide from the slide machine or lantern and put the mask (*B*) in its place. Focus the light on the disk and start the motor, using slow speed at first. An object placed in front of the disk will then be scanned with a moving spot of light and will become illuminated. Why are the holes in the scanning disk arranged in the form of a spiral?

Television in the classroom. ***Experiment 75.***[1] This experiment showing the principles of scanning, transmitting, and receiving pictures by radio can be set up in a few minutes with materials that are found in most science classrooms. A slide machine, a 12-inch disk of stiff cardboard, and a small electric fan motor are all that is necessary to perform the experiment. If a small electric fan is not available, any other small motor with speed that can be adjusted will do if the disk can be securely fastened to it, or if the disk can be rotated by hand. Assemble the apparatus as in Fig. 307.

The disk is first divided into thirty-two equal parts. This can be easily done by first dividing it into four equal parts by drawing perpendicular lines through the center. The quarters are then divided into eighths by bisecting the angles made by the perpendicular lines. The eighths are divided into sixteenths and the sixteenths into thirty-

[1] This experiment was provided by Dr. Martin L. Robertson and is here included by his permission. The experiment is intended as a teacher demonstration.

seconds in the same manner. A small round object (about 1 inch in diameter) is wrapped with a piece of string and fastened on the center of the disk. A slip knot is tied in the end of the string and a pencil is placed in the loop. The other end of the string is fastened at some point on the circumference of the central round object. The spiral is described by starting the line at *A* on the circumference of the disk and moving the pencil over the surface of the cardboard while keeping the string tight. The string shortens itself as the pencil is moved round the disk, and a spiral line is thus produced. One-eighth inch holes should be drilled or punched at the intersections of the spiral and the radial lines.

The disk can be fastened to the blades of the fan motor by punching holes in the disk. Fine wire or string can be used to fasten the disk to the fan blades. The disk must be fastened securely lest the centrifugal force of the disk cause it to break away from its fastenings and injure someone.

To show how a person or a picture is scanned at the studio of a television station, the slide machine is set up as shown in Fig. 307, and the light from the slide machine is focused on the disk. No slide is placed in the machine, though a cardboard mask such as is shown at *B* will concentrate the light on a small part of the disk. The subject to be "televised" is placed in front of the disk in such a manner that the light passing through the holes will pass over it. A projection lens placed between the subject and the disk will make it possible to scan a larger subject, but it is not necessary. If the disk is turned slowly, the spot of light will pass over the subject, following a different path for each hole in the spiral. When the motor is started, the subject will appear to be completely illuminated all of the time, because the eye cannot follow the rapidly moving spot of light. The photoelectric cell can easily follow the spot of light and change the light values into a varying electric current.

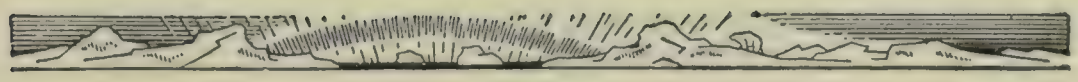
To demonstrate how images are received, place a slide in the slide machine, start the motor, and focus the picture on the wall or a screen. The picture will appear almost as clearly as it would if the moving disk were not in the path of the light.

Self-test on Problem XXV-C. (*Do not write in the book.*) **1.** The photoelectric cell is used to change *sound* energy to *electrical* energy.

2. Like radio, television depends upon the changing flow of *protons*.

3. Television is in a *less* advanced state of development than radio.

4. A scene is transmitted by television *a small part* at a time.



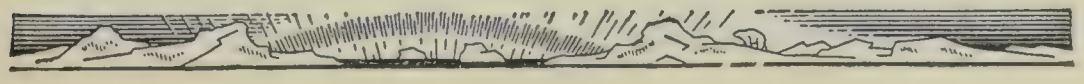
UNIT X · *Light Energy and Man's Uses of It*

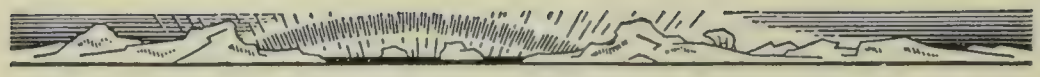
PROBLEMS DISCUSSED IN THIS UNIT

There is no factor in our environment more important to us than sunlight. Because the sunlight always returns after darkness, we have come to take it for granted just as we do other things that are very familiar. Without the light waves and other waves which sunshine contains, there could be no life on the earth. With the aid of sunshine green plants manufacture sugar and starch, and these, directly or indirectly, are the basis of all the food in the world. Sunshine, moreover, kills many kinds of disease germs. It is necessary to the health and growth of most living things. Also, many of the pleasures of life are gained through the beauties of color, and color, as we shall soon learn, is light.

Although the importance of sunlight is evident, can you imagine what it would be like to live in constant sunlight or with no light except sunlight? For many thousands of years ancient men had no other light. Finally they discovered how to use and control fire. Before that discovery they had to stop most of their activities at sunset. Progress from the use of a fire for light to the use of modern electric lighting is one of the most interesting chapters in the history of science. In our time much of the important work of the world and a large part of our recreation are carried on with the aid of artificial light. This unit discusses natural and artificial light and some of their important applications. The problems are these:

What are some important characteristics of light energy?
What are some important phenomena of color?
How is scientific knowledge applied in natural and artificial lighting?
How is electricity used in artificial lighting?
How does the eye function in the use of light?
What are the construction and functions of some common optical instruments?





Chapter XXVI · Light in Everyday Life

Questions this Chapter Answers

What is the nature of light?
What are luminous, nonluminous, transparent, translucent, and opaque objects?
How is light reflected and diffused?
Does light travel in straight or in curving lines?
What is the nature of shadows?
What causes objects to appear to be colored?
What is refraction of light?
How is knowledge of color used in dyeing cloth?
What is the relation of light to the color of the sky, the aurora borealis, and the rainbow?
What is good practice in the use of natural lighting?
What are the various means of artificial lighting, and how does each function?

Problem XXVI–A · What are Some Important Characteristics of Light Energy?

Light a form of energy. Until a few hundred years ago it was thought that light was a special quality or ability of the eye. The eye was thought to seize upon objects with some sort of invisible means, and in some way to give an idea of the object. This theory seems foolish to us now, but we should recall that nobody has even yet suggested a theory that accounts satisfactorily for *all* the phenomena of light. The leading scientists are generally agreed, however, that light is a form of energy, and that it travels, like radiant heat and radio, by means of waves. Light, radiant heat, radio, and X rays are *known* to travel at the same speed, about 186,000 miles per second.

Luminous and nonluminous objects. Luminous objects are those which give off light. Nonluminous objects are those which do not themselves give off light, but which reflect more or less of the light which comes to them from luminous objects. The sun and other stars, lighted lamps, and fires are familiar examples of luminous objects. The moon, ourselves, the atmosphere, and this book are examples of nonluminous objects.

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FIG. 308. Turn the picture upside down. Is your image reversed in the same way when you look into an ordinary mirror? Test this by looking into a mirror placed on the floor

Translucent and opaque bodies. You are familiar with the fact that light passes through certain bodies such as the air, parchment or silk lamp shades, and paraffin paper, but will not pass through other bodies, such as bricks and boards. Objects through which light passes are said to be translucent. Objects through which light does not pass are said to be opaque. Light travels through most translucent bodies in such a way that objects can be seen more or less clearly through them. Through certain other translucent bodies, however, for example, frosted-glass windows and parchment or silk lamp shades, the light passes in such a way that objects cannot be seen through them. Those translucent bodies, such as the air, ordinary window glass, and water, through which light passes in such a way that objects may be seen very clearly through them are said to be transparent.

***Mirrors reflect images.** Whenever light energy strikes an object, some of the light is reflected, some is absorbed, and, if the

object is translucent, some passes through the object. A mirror is any opaque object with a surface smooth enough to reflect the

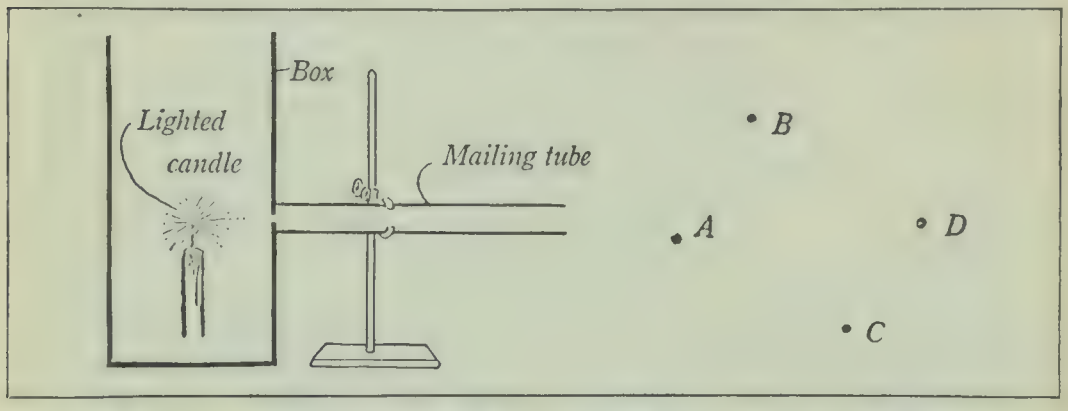


Fig. 309. **Exercise on Scientific Method (Using Controls) :** How do the various points, *A*, *B*, *C*, and *D*, serve as controls?

light in such a way as to show an image (picture) of objects that are in front of the surface. The light is reflected from the mirror to the eye. The eye catches the image, which appears to be behind the mirror.

The first mirrors probably were pools of water (Fig. 308). Later, men used plates of polished metal. Now we use glass coated with silver or with an alloy of tin and mercury. Aluminum is successfully used for the reflecting surface of the 100-inch telescope of the Mt. Wilson observatory.

Diffused light. When light is reflected from a rough surface it does not give an image, because the reflected light is scattered in all directions. Light thus reflected is called diffused light. When the sunlight passes through the air, some of it is diffused by the floating dust particles. This diffusing, or diffusion, of light is the cause of the twilight after the sun has gone down. Explain.

Direction of light movements. ***Experiment 76.*** Does light travel in straight or in curved lines? Light a candle and place it in a cardboard box without a cover. Make a small hole in the side of the box at the same height as the flame. Adjust a mailing tube with the end against this hole in the box and pointing away from the box, as in Fig. 309. At various points in the room, as indicated by *A*, *B*, *C*, and *D* in Fig. 309, find out whether you can see the candle flame through the hole in the box.

In passing from the candle flame to your eye, does the light travel in a straight line or in a curved line?

When children play hide and seek, the one who is "it" can often hear the others who are hiding when he cannot see them.

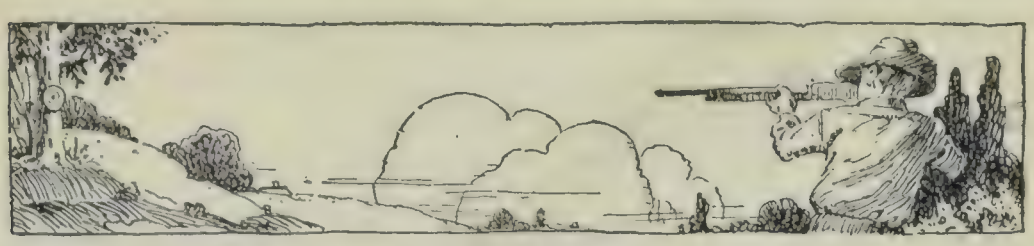


FIG. 310. Self-test on Scientific Principles: How does this illustrate the principle "Light travels in straight lines"?

This is because sound waves will bend round corners, but light waves will not (Fig. 310). Shadows furnish a familiar means of proving that light travels in straight lines.

Shadows. If you observe a shadow, you will note that the middle of it is very dark and that its edges are less dark. Thus, if a bright light is thrown upon a ball held near a wall, the shadow will look like the one in Fig. 311. Try this. The dark part of the shadow is called the umbra. The lighter part is called the penumbra. The umbra receives no light directly from any part of the source of light, that is, the lamp, while the penumbra receives light directly from part of the source of light. If you stood with your eye in any part of the umbra and looked directly toward the source of light, you could not see any of it. But if you stood with your eye in any part of the penumbra and looked directly toward the source of light, you could see part of it.

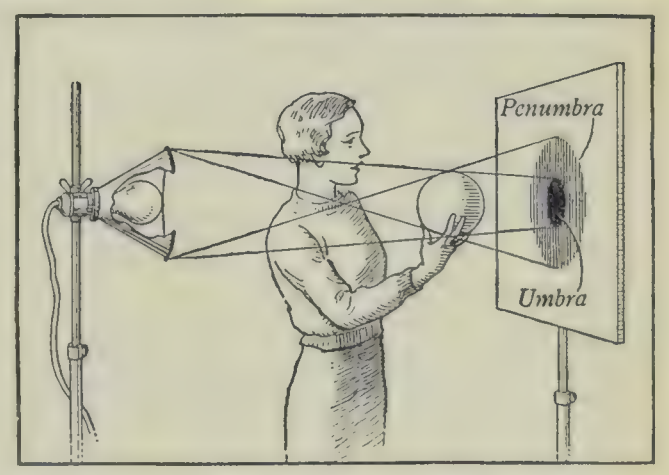


FIG. 311. How shadows are caused. In what ways is this figure like Fig. 205, p. 298?

Refraction. *Experiment 77.* Is light refracted, that is, does light change its direction as it passes from one transparent substance (water) into another transparent substance (air)? Put some object, such as a

pebble or a penny, in a dish or a cup. Stand so that as you look over the edge of the dish you can see about half the pebble. Without changing the position of your eye, pour water into the dish gently so as not to move the pebble. Can you now see the whole pebble? half of it? any of it? Make a complete statement answering the question at the beginning of this experiment.

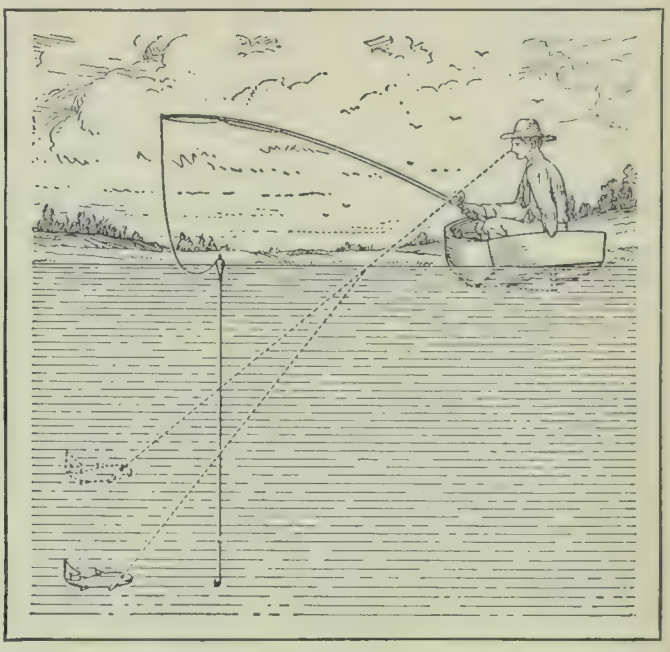


FIG. 312. Refraction of light. The boy and the fish can each see the other because each reflects sunlight to the other. The light from the boy is refracted as it passes from the air into the water. The light from the fish is refracted as it passes from the water into the air. Does the refraction of the light make the boy look to the fish to be nearer the water than he is? Can you draw a diagram similar to this in support of your answer?

Experiment 78. Does refraction of light make a fish look nearer to the surface than it really is or farther below it? Stand some object, as a small weight, upright in a glass of water. Let the top of the weight represent a fish that is swimming in the water. Now look directly down into the glass and, without changing the position of your eye, place your finger against the outside of the tumbler opposite where the top of the weight looks to be. Without moving your finger from the glass, look through the side of the glass to see whether your finger is above or below the top of the weight. Make a complete statement answering the question at the beginning of this experiment.

If you hold a pair of glasses a foot or so from your eyes and look through them at some object in the room while you turn the glasses this way and that, the object will seem to change its position. When the light from the object passes from the transparent air into the transparent glass, it changes its direction. When it again passes from the glass into the air on its way to your eyes, it changes direction once more. The object seems to

change its position because not all parts of the glass are equally thick. The light therefore is bent more wherever it has to travel farther through the glass. This bending of light rays, or changing of the direction of light as it passes from one transparent substance into another, is called refraction (Fig. 312).

You will remember that the atmosphere becomes denser the nearer it is to the earth's surface. The light from the heavenly bodies, therefore, is refracted; that is, it changes its direction as it passes through the air and is bent into a sharper and sharper curve as it passes through denser atmosphere near the surface of the earth. For this reason we are able to see the sun a little before sunrise and a little after sunset.

Self-test on Problem XXVI–A. (*Do not write in the book.*) **1.** Select from the following list of items those which are luminous, nonluminous, transparent, translucent, and opaque: (1) a fish's tail; (2) a frosted electric lamp when it is lighted; (3) a piece of tissue paper; (4) a magazine which is open in a strong light; (5) a diamond in bright light; (6) a lighted match; (7) fingernail; (8) a watch dial which can be read in the dark; (9) cellophane; (10) the moon.

2. Mirrors produce images by *refraction.*

3. When light passes from air into water it is very largely (1) refracted; (2) reflected; (3) absorbed; (4) diffused; (5) destroyed.

4. Light which strikes a rough wall is chiefly *refracted.*

5. As light continues to pass through the same substance it travels in *curving* lines.

6. If the atmosphere were of uniform density we should *scarcely* see the moon before it rises or after it sets.

7. The surface of a mirror must be smooth in order to *diffuse* the light.

Problem XXVI–B · What are Some Important Phenomena of Color?

***Colors.** If you look through a glass prism at any object, the outlines of the object will appear to be beautifully colored. If now you hold the prism in direct sunlight, you will see a beautiful rainbow-colored spot of light where the light has passed through the glass. The explanation is this: Sunlight is known to be made up of all the colors of the rainbow. These colors blend so gradually

one into the next that we cannot tell where one color ends and the next color begins. Of the thousands of colors that make up the sunlight we are able to distinguish clearly seven color bands — violet, indigo, blue, green, yellow, orange, and red. When sunlight passes from air into glass, the different colors that make up the white sunlight are refracted. The colors, however, are not refracted equally. The violet is refracted most, the indigo a little less than the violet, the blue a little less than the indigo, and so on through all the colors to red, which is refracted least (Fig. 313).

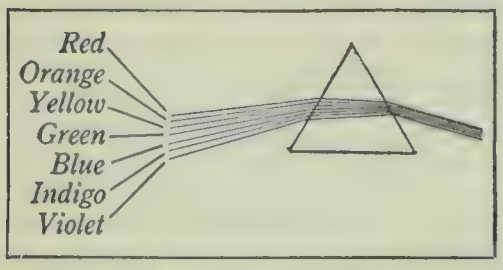


FIG. 313. Why do we see rainbow colors in diamonds, in cut glass, and in expensive crystal beads?

***What causes objects to be colored?** The color of this book cover is blue. The reason is that when light strikes the book, a less amount of the blue light is absorbed than of the other colors, although some light of all the colors is absorbed. The result is that the book appears blue because it reflects back to our eyes more blue light than light of any other color. Similarly, grass and trees are green (Fig. 314), because they absorb less green light than light of all the other colors. Hence more green light remains to be reflected back to the eye. An object looks white when all the colors of the sunlight are reflected to the eye equally. An object looks black when all the colors composing the sunlight are absorbed. When paints are mixed together, the resulting paint has the color of that part of sunlight which is least absorbed. This color is therefore most abundantly reflected.

When objects are transparent or translucent, so that part of the light passes through them, they have the color which is least absorbed in passing through. Water is colorless because all the colors of light pass through in equal amount. The light behind a piece of blue glass is blue because when all the colors enter the glass, less blue light is absorbed by the glass and therefore more blue light than light of other colors passes through.

Color in cloth. More than five thousand dyes are known, most of which can be manufactured from substances distilled from coal tar. About nine hundred dyes are used.

Before the World War most of the dyes used throughout the world were made in Germany. Our chemists had not yet learned to make many of these dyes, because we had been obtaining our dyes from Germany, where the secret of their manufacture was carefully guarded. During the World War, however, when dyes could no longer be procured from Germany, our chemists began to experiment for the purpose of finding out how we might make our own dyes. They were so successful that they discovered not only how to make many of the dyes which formerly had to be brought from Germany but also how to make many new dyes.

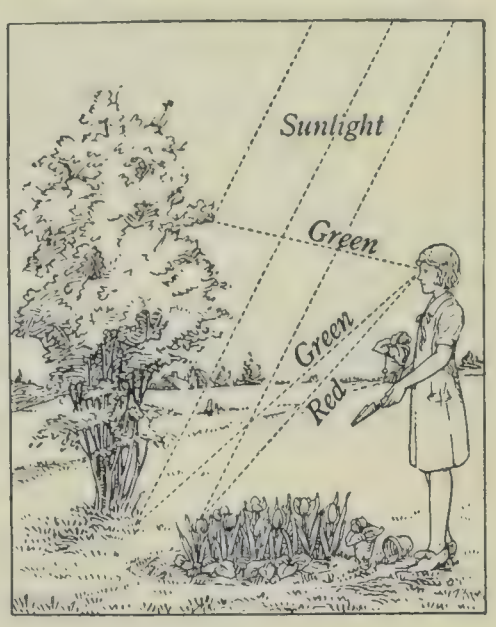


FIG. 314. Can you explain why leaves and grass appear green, and tulips red?

*Woolens and silks are usually dyed readily by steeping them in water in which the dye is dissolved. Cotton, however, does not dye "fast" with many colors; that is, the colors wash out when the cotton has been dyed with them. Therefore cotton cloth is first soaked in a solution of certain compounds of aluminum, tin, chromium, or iron. The cloth will then dye fast if it is first exposed to steam before it is steeped in the dye. If a design is wanted instead of a solid color, the design is printed on the cloth in one of the metal compounds which we have just named. After this printing the cloth is exposed to steam and is then steeped in the dye. The dye remains fast in the metal compound and can be removed from the rest of the cloth, leaving the design.

***The sky.** The sky is bright during daylight hours because the particles of air, of moisture, and of dust scatter some of the sun's light which is passing through the atmosphere. Above the atmosphere the sky is black even at noon. The sky looks blue to us probably because of the diffusion of the light by the dust particles in the air. The short blue waves are scattered more than are the longer red ones.

***Aurora borealis.** In the states farthest north and in Canada the aurora borealis, or northern lights, are often observed. These

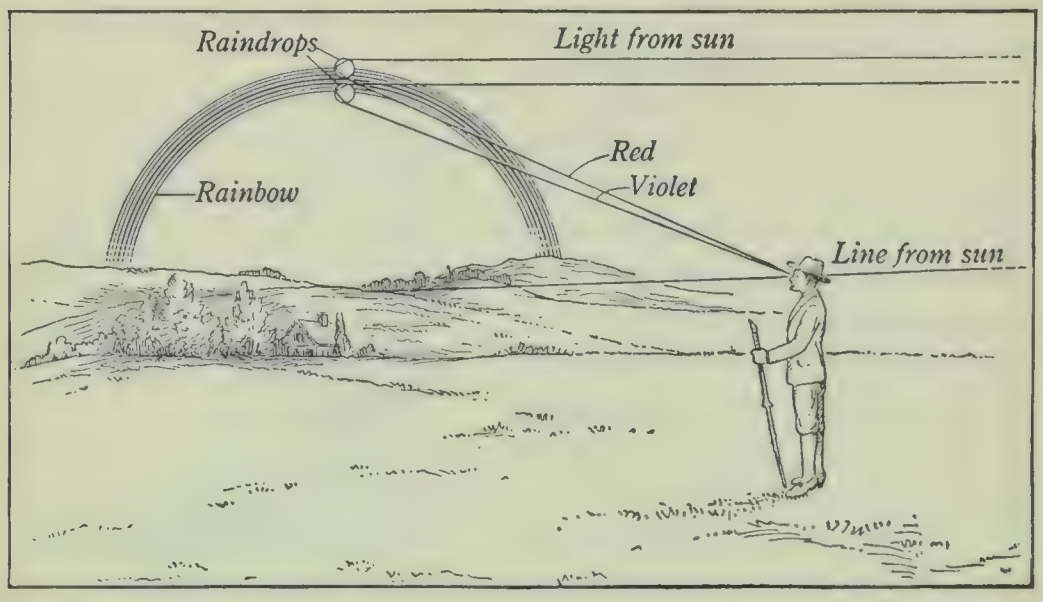


FIG. 315. Diagram showing how a rainbow is formed. Note how the light is refracted as it passes into and out of the drops, and how the light is reflected from the backs of the drops. The paths of only the two outside color beams are shown here. Why do we never see a rainbow at noon?

are irregular patches or changing columns of light or brilliant areas of color in the sky. Their exact nature and cause are not yet known. It is believed, however, that they are in some way related to sunspots. Also, they are thought by some scientists to be due to electrical discharges.

***The rainbow.** The rainbow is formed whenever the white sunlight is refracted through raindrops in such a way that we see the separate colors. We can never see the rainbow unless our backs are to the sun. The light is then refracted through the drops of water and reflected from the opposite side of the drop to the eye (Fig. 315).

Experiment 79. What is the true shape of the rainbow? Adjust a hose so that it makes a fine spray. Stand in the direct sunlight early in the morning or late in the afternoon, with your back to the sun. Observe the rainbow as you spray the water directly away from the sun. This experiment may be performed after dark by using an automobile headlight as a source of light instead of the sun. Is this rainbow more

or less nearly a perfect circle than the rainbow seen in the sky? Can you explain why? Which color is inside in your rainbow? Which color is outside? Perhaps you can see a double rainbow, one inside the other. If so, are the colors arranged in the same order in both?

Self-test on Problem XXVI–B. (*Do not write in the book.*) **1.** Sunlight consists of *one color* of light.

2. A lemon looks yellow because it *absorbs* more rays of yellow light than rays of other colors.

3. Dyes are largely made from _ _(?)_ _.

4. The sky looks blue because of the *reflection* of light in *one direction.*

5. When we see a rainbow, the sunlight is both _ _(?)_ _ and _ _(?)_ _ as it passes through the raindrops.

Problem XXVI–C · How is Scientific Knowledge Applied in Natural and Artificial Lighting?

***Natural light.** The sun is the earth's main source of natural light. The other stars are too far away to furnish much light to the earth. The sky and the moon are the only important sources of natural light besides the sun. Neither the sky nor the moon has light of its own. They merely reflect to us some of the light which reaches them from the sun.

Sunlight in the home. Out of doors in the bright sunshine the light is about ten times as bright as it is in the shade. Out of doors in the shade the light is brighter than it is near the windows inside a well-lighted house. Away from the windows the light in many houses is too dim for reading or for many other purposes.

The daylight comes slanting through the windows into our homes. Most of our rooms get little direct sunlight. They are lighted largely by diffused sunlight. This is reflected mostly from clouds and dust particles in the air. All the direct sunlight passes through the window at the same angle, but the diffused sunlight enters at every possible angle (Fig. 316).

Houses are usually provided with from one fifth to half as much window area as floor area. A house built close to other houses or in a grove of trees needs more window space than a house by itself in the open. Moreover, windows frequently fail

to admit sufficient light because of heavy curtains and shades. Window shades in living rooms are needed chiefly to shut out the direct sunlight when it is unpleasantly bright and dazzling. Light-colored translucent shades are better than dark-colored opaque ones. Why?

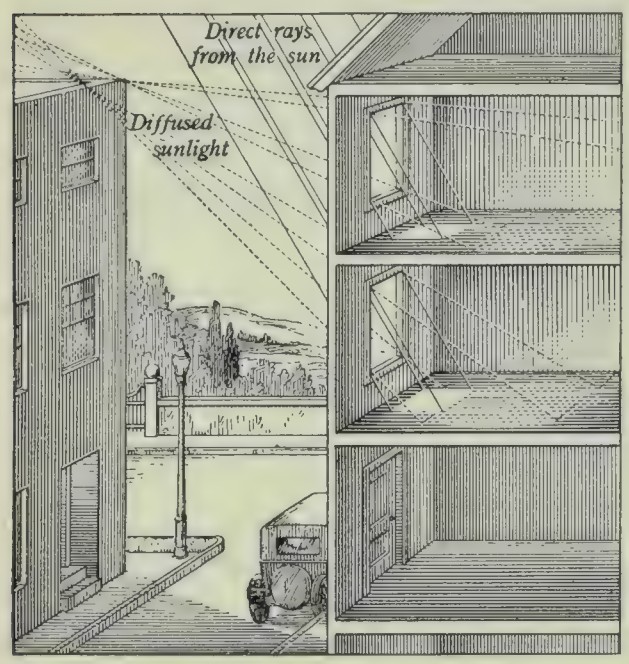


FIG. 316. Why should windows extend as nearly to the top of the room as possible?

The effects of color on lighting. The amount of natural light that brightens the insides of houses does not depend entirely on the amount of window space or on the kind of shades and the way in which we use them. The color of the walls and ceiling and of the woodwork and furniture has much to do with the amount of light in a room.

Much of the light we use is reflected one or more times from the floor, walls, ceiling, or furniture before it reaches the place where we use it. Light colors absorb less light than dark colors. If we want to diffuse as much light as possible throughout the rooms, therefore, we should use light colors for our walls and ceilings. A room in which the floor, the hangings, the furniture, and the walls and ceiling are all dark is sure to be dim and gloomy. Light oak-wood finish reflects more than twice as much light as dark oak finish and about four times as much as walnut or mahogany finish. A wall or ceiling of very light gray reflects about four times as much light as one of dark gray. Dark shades of almost any commonly used color frequently absorb as much as four fifths of all the light that strikes them, leaving only one fifth to be diffused about the room. The delicate light shades of yellow and red not only act as good reflectors of light but also give a cozy and cheerful appearance to the room. The reflection from a glossy surface is apt to be glaring and to strain the eyes.

***Artificial light.** Fires were man's first source of artificial light. At first he had to remain beside the fire which gave him light, but finally he learned to carry a blazing branch or knot away from the fire. Thus the torch was the first lamp.

***Oil lamps.** Thousands of years passed before man learned to make crude stone lamps. At first these lamps were merely flat hollow stones. Oil was put into the hollow, and a crude wick of rush or twisted flax or cotton was stuck into the oil and lighted. Later man made these lamps of pottery, and still later of bronze and other metals. The first oil lamp with a chimney was invented only a little over two hundred years ago. Kerosene-oil lamps came into use about seventy years ago and are still in use where electricity is not easily obtainable.

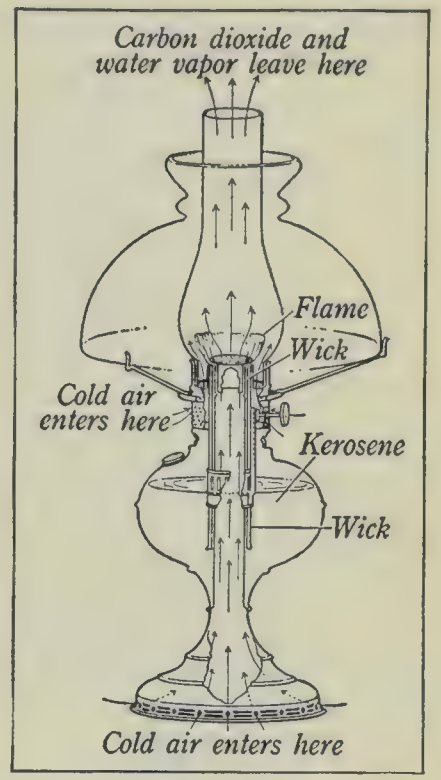


FIG. 317. Diagram of a kerosene lamp. In what ways is the burning lamp like an open fire (Fig. 145, *B*, p. 212)?

We have learned in previous chapters that the common fuels contain compounds of carbon and hydrogen. When the oil at the top of the wick in oil lamps is heated to the kindling temperature, the oxygen in the air combines with the carbon and the hydrogen in the oil to form water and carbon dioxide. The water is, of course, in the form of a vapor. But not all the carbon is oxidized, and the incandescent solid particles of carbon in the flame give off the light.

*In the kerosene lamp (Fig. 317) the oil rises through the porous cloth wick by capillarity.[1] When the wick is lighted, the oil at the top of the wick burns, setting up convection currents.

*The wicks of kerosene lamps should be soft, well-fitted, and long enough to trail about two inches on the bottom of the oil reservoir. As soon as these extra two inches have been burned and trimmed away, the wick should be replaced. The lamp should be filled each day so as to prevent too large a space above the oil

[1] *Capillarity* (kap i lair'i ty): the rising of liquids into very small tubes.

in the reservoir. There is danger in lifting and carrying a lighted oil lamp or in extinguishing it by blowing *down* the chimney, for if the flame should be forced into the oil vapor an explosion might result. It is safer to blow *across* the chimney. If any sediment is allowed to collect in the oil reservoir, this will close the capillaries of the wick so that it will not be able to supply sufficient oil to the lamp.

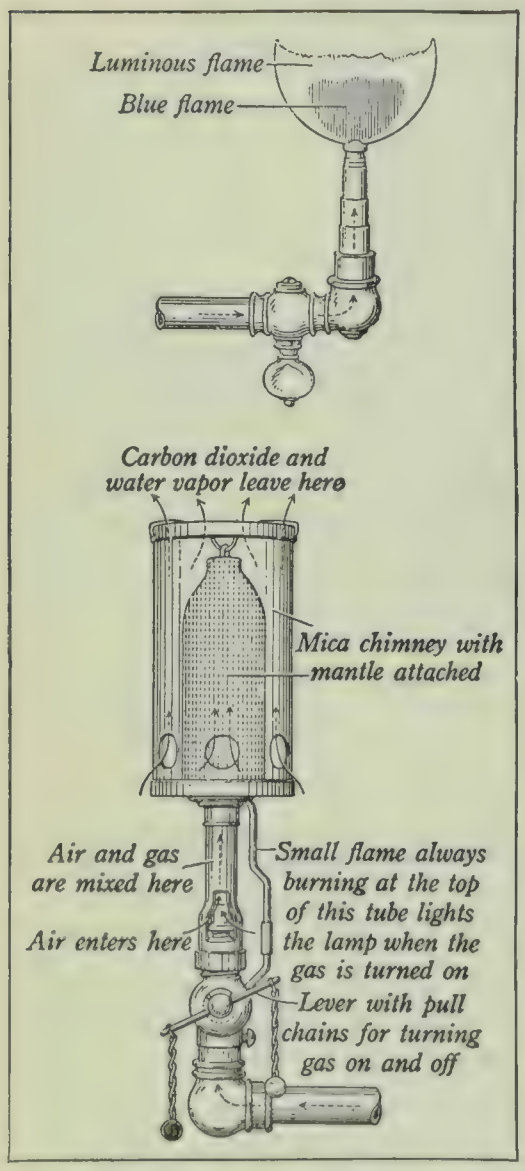

Luminous flame
Blue flame
Carbon dioxide and water vapor leave here
Mica chimney with mantle attached
Air and gas are mixed here
Air enters here
Small flame always burning at the top of this tube lights the lamp when the gas is turned on
Lever with pull chains for turning gas on and off

FIG. 318. Early and modern types of gas lamps. Years ago in hotels where gas lights were used, the sign "Do not blow out the gas" was sometimes put up in bedrooms. Explain

Candles. Candles were known about four thousand years ago, but were too expensive for general use until the fifteenth century. They were an important source of light in the early history of this country until the kerosene lamp became popular. They still find a use on dining tables, where they furnish a soft, pleasing light. But they are apt to interfere with the view across the table, and, if unshaded, to strain the eyes.

Gas lamps. Natural gas began to be used as a fuel and for lighting early in the last century. Later, heating gas was made from soft coal. Where electricity is not yet available we find these two kinds of gas still being burned for light.

The early gas lights were merely gas pipes. The gas was lighted as it escaped from the end of the pipe. Later the open ends were equipped with various devices to spread the flame (Fig. 318). The oxygen in the air combines with the carbon and hydrogen

compounds in the gas to produce water and carbon dioxide, as always happens when any fuel burns. Some of the carbon, however, is not oxidized. Incandescent solid particles of unburned carbon cause most of the light.

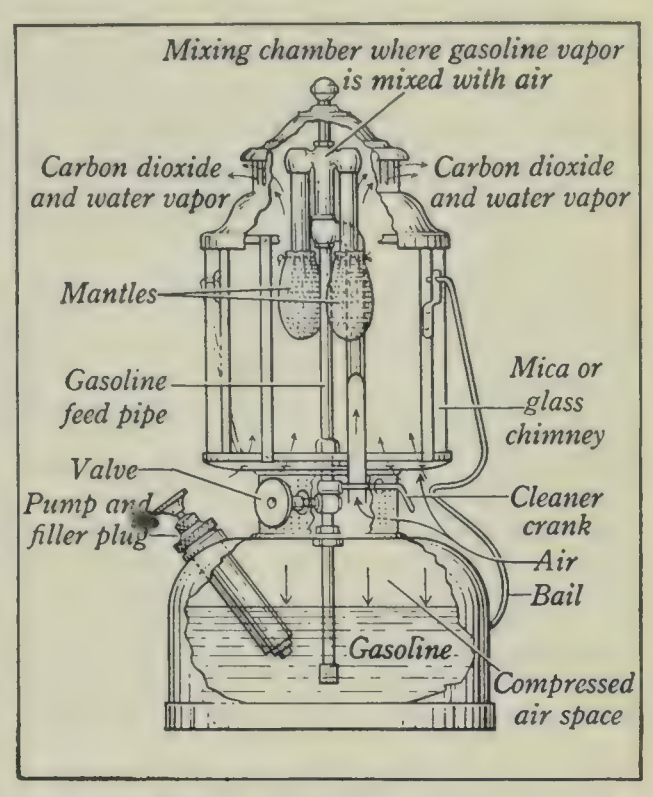


FIG. 319. Diagram of a modern gasoline lantern. Compare this lantern with the modern gas lamp (Fig. 318)

*Gas mantle lamps. Later the gas lamp was greatly improved by the invention of a mantle. This thimble-shaped mantle is woven out of cotton or artificial silk and is saturated with solutions of compounds of thorium and cerium, two rare metals. A burner much like that of the gas stove is fitted over the gas pipe. The mantle is hung over this burner (Fig. 318). The amount of air allowed to enter with the gas is controlled so that the carbon is all oxidized. The intense heat from the blue flame heats the mantle to incandescence, giving a much brighter and whiter light than does the open-flame type.

Gasoline lamps. Gasoline lamps, much like mantle gas lamps and greatly superior to kerosene lamps, are finding an increasing use in places where neither gas nor electricity is yet available. Also, gasoline lanterns are taking the place of kerosene lanterns for most purposes. The gasoline in the well at the base is forced up to the mantles by compressed air (Fig. 319). The gasoline must be heated until it evaporates and forms a vapor before it is burned in the mantle. Air entering a separate pipe mixes with the gasoline vapor. The light is produced in the same way as in the mantle gas lamps. Such a lamp gives a soft light almost equal in brightness to that of a hundred-fifty-watt electric lamp. It burns for about fifty hours on one gallon of gasoline.

Self-test on Problem XXVI–C. (*Do not write in the book.*) **1.** Venus is a source of some *natural* light.

2. If there were neither clouds nor dust in the air, our houses would be *more* brightly lighted during the *daytime* than they now are.

3. Windows equipped with shades which are pulled up from the bottom admit *more* sunlight than would the same windows with shades which are pulled down from the top.

4. Light colors *absorb less* light than dark colors.

5. Can you explain the action of the kerosene lamp by choosing the correct term from each pair in the following paragraph?

When the wick is lighted, the air above the wick becomes *cooler warmer.* It therefore *expands contracts,* making the air pressure inside the chimney *greater less* than the air pressure outside the chimney. More air is therefore *sucked in pushed in* through the air holes by *the partial vacuum inside the greater air pressure outside.* Fresh supplies of *oxygen carbon dioxide* are thus supplied to the flame.

6. Gasoline lamps are somewhat *superior* to kerosene lamps.

Problem XXVI–D · How is Electricity Used in Artificial Lighting?

The incandescent lamp. Many scientists contributed to the invention of the incandescent electric lamp. The first successful carbon-filament lamps, however, resulted from the experimenting of J. W. Swan and Thomas Edison about sixty years ago. In the early incandescent lamps a carbon filament in a vacuum globe (Fig. 320, *A*) was heated to incandescence by the passage of an electric current through it. The carbon-filament lamp is used very little now.

*Several electric lamps have been invented in which a metal filament is used in place of the carbon (Fig. 320, *B*, *C*, *D*). Tungsten-filament lamps are now used almost entirely, because they can be operated at much higher temperatures than carbon and last even longer. The filament of the earlier tungsten lamps was placed in a vacuum globe, like that of the carbon lamps. Recently, however, gas-filled bulbs have rapidly replaced the vacuum globes in the larger lamps.

Gas-filled lamps. Nitrogen was used in the first gas-filled tungsten lamps. Lamps filled with pure nitrogen are no longer

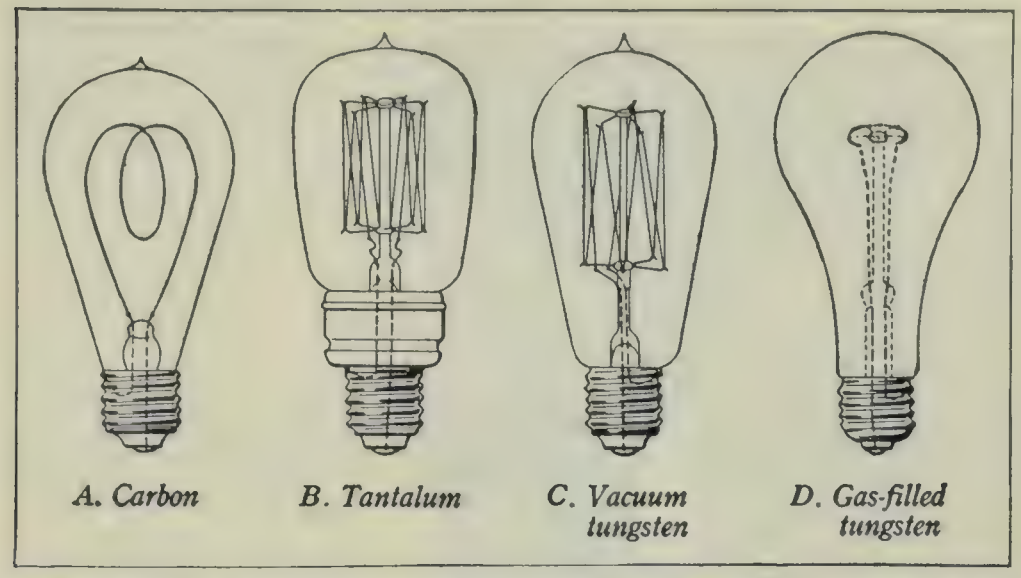


FIG. 320. Early and modern types of electric lamps. You cannot afford to burn lamps like *A*, *B*, and *C*, because they use too much electrical energy for the light they give. *D* reduces glare by diffusing the light because it is frosted. It is easily kept clean, because it is frosted on the inside. Why cannot these globes be filled with air?

manufactured, because argon, a heavier, inactive gas, has been found to be superior to nitrogen for this purpose. Present-day lamps, therefore, are filled with a mixture of 85 per cent argon and 15 per cent nitrogen. It is probable that practical means will be found to make gas-filled lamps using other inactive gases which will prove even more satisfactory than argon.

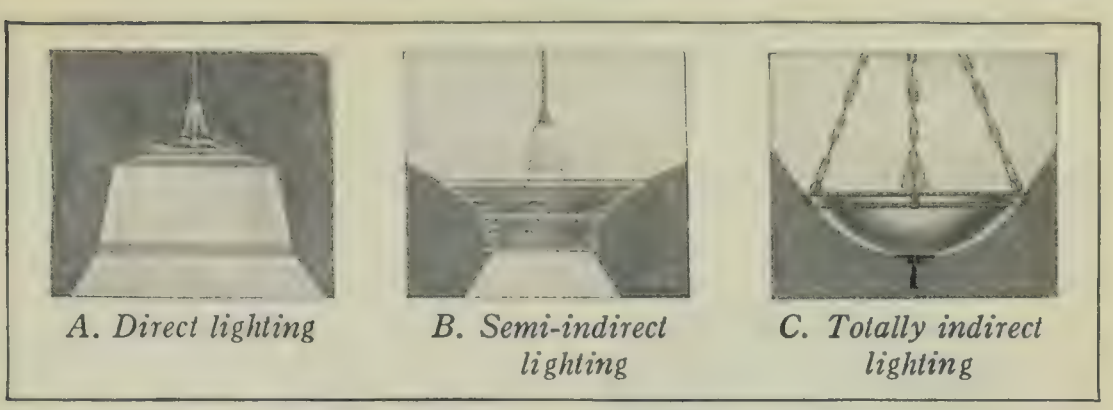
*The gas-filled lamps give a better quality of light than the vacuum tungsten lamps and use less electrical energy; in other words, gas-filled lamps are more efficient than vacuum lamps, especially in the larger sizes. The small vacuum tungsten lamp is still widely used, because suitable methods of making small gas-filled lamps, that is, those of twenty-five watts or less, for ordinary house circuits (110 volts), have not yet been found.

Gas-filled lamps for signs. Before 1923 all the electric signs in this country were made up of separate electric lamps of various colors. Our attention is now attracted by beautiful orange-red, blue, yellow, and green signs in which often a whole word or a design is made up of only one lamp. These lamps are glass tubes

made in any length and bent into any desired shape. All the air is first exhausted from the tube, then neon, argon, or helium (rare gases which exist in the air) and sometimes a little mercury are admitted to the tube. It is then sealed in a flame. The pressure of this gas within the tube is very low. The electric current, passing through this gas between terminals that are sealed into the ends of the tube, produces the illumination. Neon gas gives orange-red light. Mercury vapor produces green or blue light. Other colors may be produced by putting more than one of these gases or the vapor of the metal cadmium into the tube and by using a special kind of glass. Such colors are more likely, however, to be produced by combining tubes each having a gas or a vapor different from that in the other tube and giving its own color. Orange-red neon lamps are being used not only for electric signs but also for lighthouse and airplane beacons and for marking airplane routes (Fig. 321).

FIG. 321. The airplane beacon on the top of the Roanoke Building, Chicago. It is 520 feet above the street. Above the orange-red tube lamps, which are white in this picture, is an 8000-candle-power revolving searchlight. **Exercise on Scientific Attitudes:** Which of the scientific attitudes (pp. 12 and 13) were possessed by the many scientists who developed the electric lamp from its earliest forms through its various stages to the modern electric lamp?

Neon house lamps. Recently small neon-filled lamps have been introduced in homes for use in halls, bathrooms, luminous house



A. Direct lighting *B. Semi-indirect lighting* *C. Totally indirect lighting*

FIG. 322. Three common types of home lighting. *C* requires more powerful lamps than *A*. Why?

numbers, or wherever a small amount of light is needed during all the hours of darkness. Some of these "glow lamps" consume as little as half a watt.

Planning artificial lighting. The same conditions which make a house bright and cheerful by daylight will make it bright and cheerful at night. It is just as important that we should have light-colored walls and ceilings for artificial lighting of our rooms as for natural lighting. It is important that our lamps be chosen and arranged so as to have the illumination bright enough in all portions of the room for whatever we want to do and so as to have at the same time the least possible strain on the eyes. There is no real saving in using too small lamps or too few. Too bright lamps, producing a glare, are likewise to be avoided.

There are at least two reasons why no lamp should burn without a shade: (1) an unshaded lamp gives a dazzling spot of light, thereby causing too great a contrast with the dim portions of the room, and (2) it causes much eyestrain whenever one looks at it.

***Types of illumination.** There are three common ways of lighting a room with electric lamps: by direct illumination, by semi-indirect illumination, or by totally indirect illumination. In direct lighting (Fig. 322, *A*) most of the light is directed downward. An ordinary lamp or a desk lamp is a good example of direct lighting.

*In semi-indirect lighting (Fig. 322, *B*) the lamps are placed in a bowl with a translucent bottom. Some of the light passes through the bottom, but most of it passes directly to the ceiling or is reflected there by the opaque reflector and the translucent bowl. It is diffused by the ceiling throughout the room.

*In totally indirect lighting (Fig. 322, *C*) the lamps are placed in an opaque bowl, which reflects the light to the ceiling. The ceiling diffuses the light about the room.

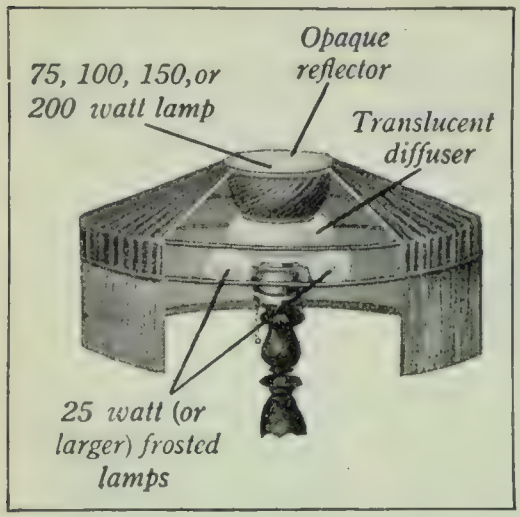


FIG. 323. From which part of this lamp will the lighting be most affected by dark walls?

An excellent type of floor lamp is shown in Fig. 323. The lamp has two separate lighting units, one direct and the other semi-indirect. The two small lamps furnish direct light for reading. The larger lamp, in an opaque reflector, lights the whole room by diffusion from the ceiling, and at the same time it diffuses enough light through the translucent bottom of the reflector to light the floor below without the aid of the small lamps.

***Relative values of the three types of illumination.** More of the light is lost by semi-indirect and totally indirect lighting than by direct lighting. But semi-indirect lighting and totally indirect lighting give a better quality of light because of the diffusion, and they give a more even illumination and less shadow.

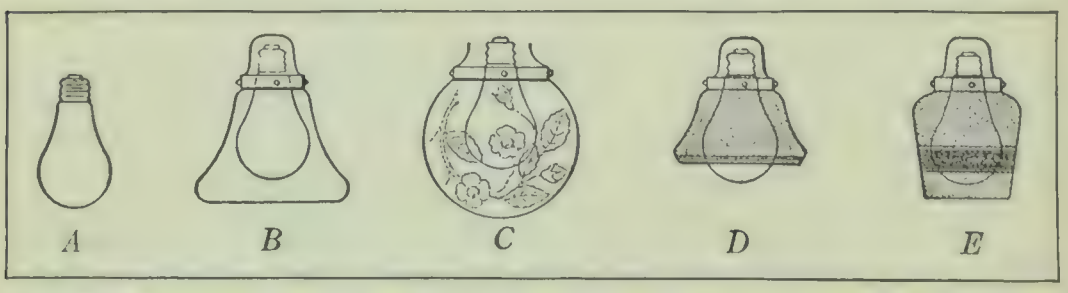


FIG. 324. Four poor types and one excellent type of lamp fixture. **Special Reports:** Make a careful study of the lighting in your school building; in your home. What changes can you suggest for the improvement of the lighting in each?

Dust forms a dark coating on the walls and ceilings and on the lamps and shades. This coating of dust may absorb more than half of all the light. Therefore it is necessary that lamps and shades, as well as walls and ceilings, should frequently be cleaned.

***Lighting fixtures.** Fig. 324 illustrates five types of lighting fixtures commonly found in homes. Of these only *E* illustrates good practice. The unshaded lamp (*A*), the lamps in transparent glass shades (*B* and *C*), and the lamp which extends below the translucent or opaque shade (*D*) should all be avoided for the two reasons which are given on page 475. Every lamp ought to be provided with a translucent or an opaque shade somewhat longer than the lamp, as in *E*.

Self-test on Problem XXVI–D. (*Do not write in the book.*) **1.** The most efficient electric lamp is one that contains (1) a carbon filament in a partial vacuum; (2) a tungsten filament in argon; (3) a tungsten filament in a mixture of argon and nitrogen; (4) a tungsten filament in nitrogen; (5) a tungsten filament in air; (6) a tungsten filament in a partial vacuum.

2. State two reasons why shaded lamps are superior to unshaded ones.

3. A book placed just below a reading lamp furnishes an example of *indirect* illumination.

4. Light reflected from the ceiling is an example of *direct* illumination.

5. The gases used in lamps are chiefly *active* gases in the air.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. When the sun sets on the moon, darkness follows *instantly*. Explain.

2. Draw a diagram showing how the sun's light is reflected to us at night from the moon.

3. Green cloth in green light looks green, and red cloth in red light looks red; but red cloth in green light or green cloth in red light looks black. Explain.

4. Many people like to pull the window shades part way down. Why does this practice shut out considerably more than half the useful light from the room?

5. When the wick of a kerosene lamp is turned too high, the lamp smokes. Why?

6. If something were placed over the top of the chimney or if the air holes were closed, the kerosene lamp would smoke and the flame would soon be extinguished. Explain.

Project. To construct a simple periscope. Fig. 325, *B*, shows a simple periscope which can easily be made out of two right-angled prisms and a hollow tube like those in which maps and calendars are mailed. In Fig. 325, *A*, is shown a still simpler one which can be made by using two small mirrors in place of the prisms.

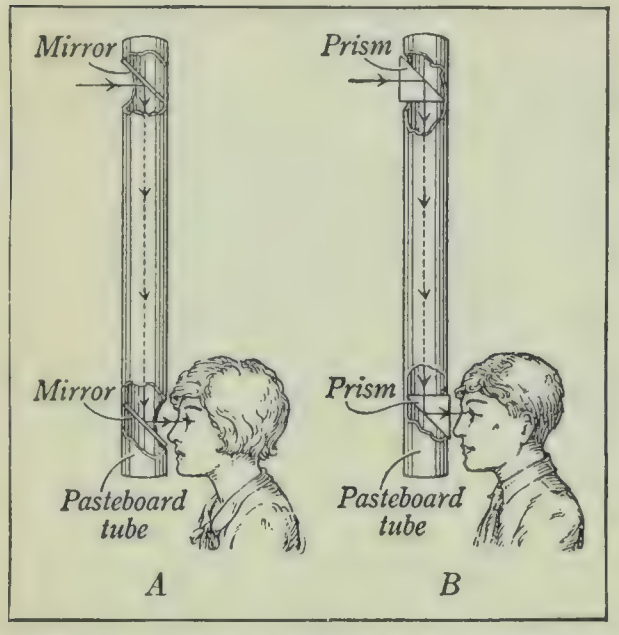


FIG. 325. Can you explain how the periscope is an application of refraction of light?

Special Reports. 1. Compare the following mirrors for likenesses and differences: an ordinary flat mirror, a round-backed mirror such as is used on automobile trucks, and a round-backed shaving mirror.

2. In what way are mirages caused?

3. How is an arc light constructed? For what purposes is it still used?

Exercise on Scientific Attitudes. John reported in his science class that he had read in the magazine section of a Sunday paper that a deep cave would be totally dark even if its walls were painted white. Which of these comments by his classmates would a scientist consider best? Defend your choice by quoting one of the scientific attitudes (pp. 12 and 13).

a. Sounds crazy to me.

b. It might or might not be true. We can't decide from just this statement.

c. I'll believe it when I see it.

d. I never believe anything I read in magazine sections of Sunday papers.

e. If it says so in the paper, it's true.

Books for Reference

HOUSTON, E. J. The Wonder Book of Light. Frederick A. Stokes Company, New York.

LUKIESH, M. Lighting the Home. D. Appleton-Century Company, Inc., New York.

Chapter XXVII · The Eye, and Instruments to Improve and Extend Vision

Questions this Chapter Answers

What are lenses, and how do they function?

In what respects does the eye resemble, and in what respects is it unlike, a camera?

How do we see objects?

What are some common-sense rules for the care of the eyes?

How are some common defects of vision avoided or corrected?

What are the characteristics of some complex optical instruments, such as the telescope, the microscope, opera glasses and field glasses, and the spectroscope?

How are photographs, moving pictures, and talking pictures, taken or recorded, and later reproduced?

Problem XXVII-A · How does the Eye Function in the Use of Light?

***Lenses.** When we studied refraction we learned that whenever light passes from air into glass, it changes its direction; that is, it bends. The thicker the glass the more the bending. Pieces of glass called lenses, shaped like those in Fig. 326, are made so as to refract light in certain ways.

In order to understand how the eye functions we must first learn something about lenses.

Experiment 80. Do objects look larger or smaller through convex and concave lenses? Hold a convex lens and a concave lens in turn near some object, such as the back of the hand or a page of printing. Copy the following and fill the blanks with the word *convex* or the word *concave* (*Do not write in the book*):

A __(?)__ lens magnifies objects (that is, makes them look larger than they do to the naked eye): a __(?)__ lens makes objects look smaller than they look to the naked eye.

An ancient convex lens (Fig. 326, *B*), which had been carved out of rock crystal at least as early as 600 B.C., was recently found in the ruins of an Assyrian palace on the banks of the river

Tigris. It is probable that the ancient Assyrians knew that convex lenses could be used to magnify objects and to light fires. Not much more was learned about lenses until centuries later. All the important optical instruments, moreover, in which lenses are used (for example, the telescope and the microscope) were invented less than one thousand years ago.

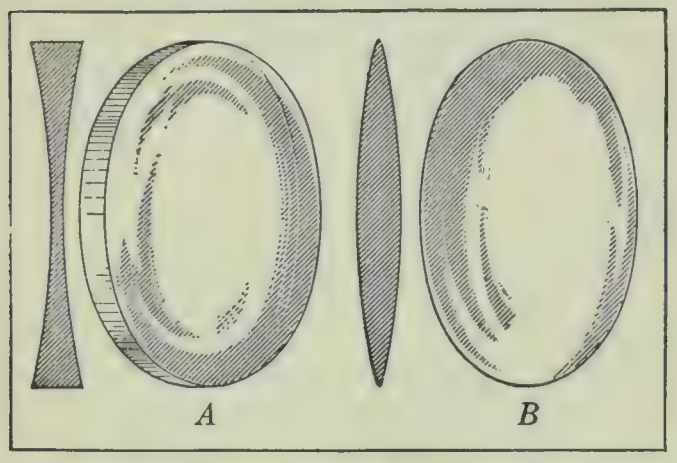


FIG. 326. *A*, a concave lens; *B*, a convex lens. Each lens is shown as it appears when partly turned toward you and when seen from the side. Compare these two forms of lens. (See "To the Student," p. xvi)

The human eye. In the eleventh century an Arabian scientist, Alhazen, made a study of the parts of the eye. He explained how the convex lens in the eye (Fig. 327, *B*) enables us to see. His writings are thought to have led to the invention of spectacles about two hundred years later by the English scientist Roger Bacon.

***The eye like a camera.** The tough covering of the eye corresponds to the box of a camera. The retina of the eye receives

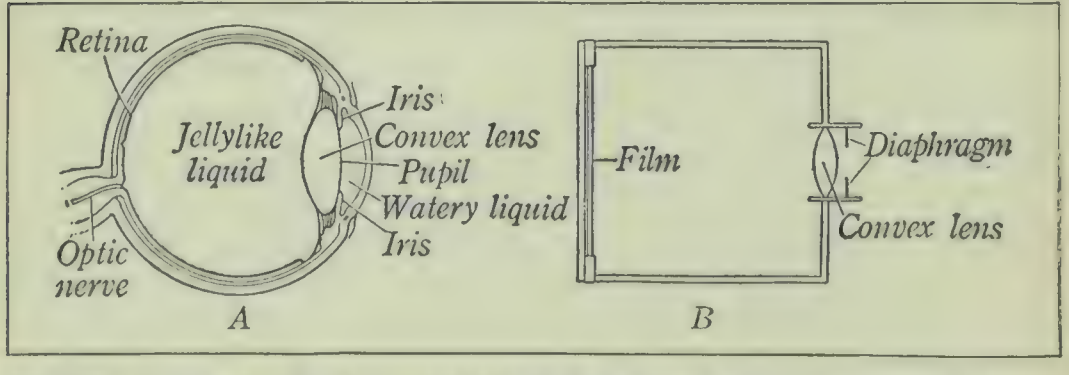


FIG. 327. *A*, diagram of the human eye; *B*, diagram of a camera. **Special Report: How high-priced cameras differ from low-priced cameras**

the image just as does the film in the camera. The iris of the eye is a diaphragm (Fig. 327, *A*, *B*). The iris controls the amount of light that enters the eye, just as the diaphragm controls the

amount of light that enters the camera. When the light is very bright, the iris closes up so as to make the pupil (the window into the eye) smaller. But when the light is dim, it opens up in order to allow more light to pass through the pupil. You can see how the iris opens and closes as the light becomes dimmer or becomes brighter, thus: Have a member of your class cover one eye with his hand so that his open eye is in darkness for a minute or so. Watch the iris of his eye as he takes his hand away. Does the pupil of the eye become larger or smaller when the bright light strikes the eye?

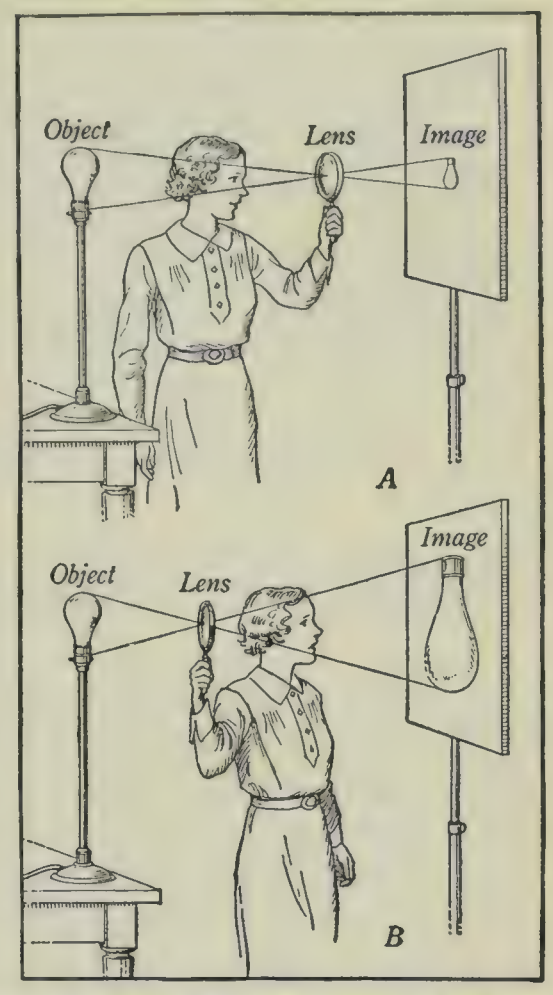


FIG. 328. Can you explain these diagrams?

Experiment 81. How do convex lenses make images? Hold a convex lens, such as a reading glass, in the window. Move a sheet of white paper back and forth behind the lens until you see on the paper an image of the scene outside the window. Is the image right side up or upside down? Now hold the convex lens very near some object. Is the image now right side up or upside down? Summarize in a single sentence the results of this experiment.

Refraction in the eye. When the light from a distant object passes through the convex lens, it is refracted to form an image which is upside down, or inverted (Fig. 328). Thick lenses refract the light more than thin ones.

*Fig. 329, *A*, *B*, indicates that thick lenses have their images closer to the lens than thin lenses do. Fig. 328 shows also that as the object (the lamp) is brought closer to the lens, the image moves farther from the lens. The retina, which receives the images

in the eye, cannot move forward and backward as we moved the screen in Fig. 329, *A*, *B*. It must stay the same distance from the

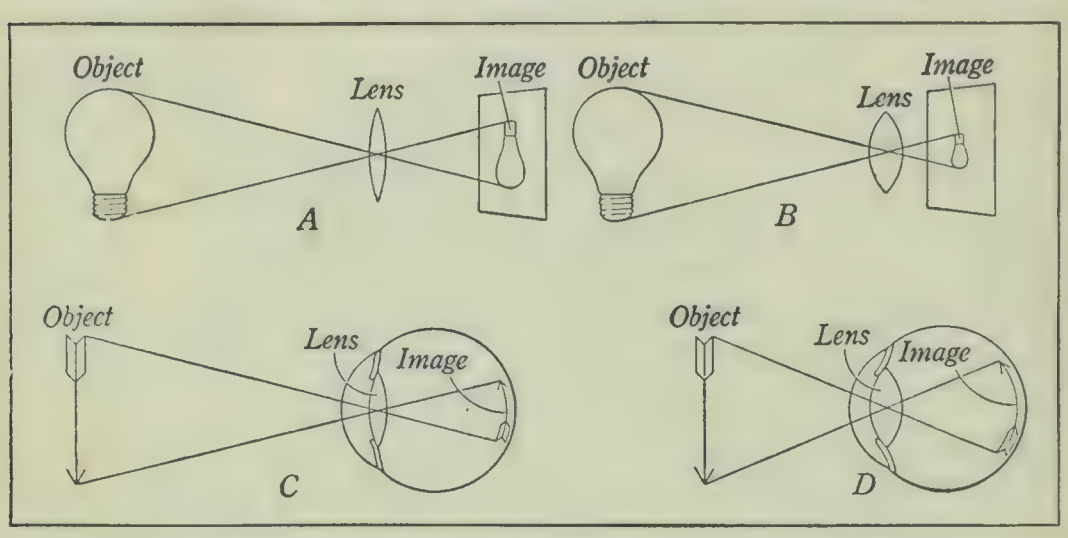


FIG. 329. How we are able to see near and distant objects. Can you explain these diagrams?

lens. The lens in the eye, however, is so constructed that it can become thinner when objects are far away and thicker when objects are near. Thus it is able to keep the image refracted on the retina (Fig. 329, *C*, *D*).

Care of the eyes. When the eye is looking at a distant object or when we are asleep, the eye muscles are relaxed[1] and the lens is as thin as it can get. When we look at close objects, the muscles contract in order to make the lens thicker. If we look at objects near the eyes for a long time, the eye muscles become tired and our eyes feel strained. When one reads for a long time, then it is better to relax the eye muscles frequently by closing the eyes for a moment or by glancing at some distant object. Many people injure their eyes by reading in too bright or too dim a light (Fig. 330). One should never read in bright sunshine or in twilight.

If you find that your eyes pain you or that you do not see clearly, it is very important that you should at once consult the best eye specialist you can find and not wait until eye trouble develops. Sometimes you can prevent serious eye troubles which might develop when you are older. Children often need glasses

[1] *Relax* (re lax′): to loosen; to relieve from strain.

before their eyes give them trouble enough to show them that they need to consult a specialist. Sometimes foolish and vain people

FIG. 330. In what ways does one picture illustrate bad practice and the other good practice in reading and writing by lamplight?

will not wear glasses at all, or will not wear them all the time that the specialist advises. Such persons are running the risk of injuring their sight permanently.

Patent medicines[1] for eye troubles. Do not buy patent medicines for the eyes. Several different kinds of drops and salves which claim to cure diseases of the eye can be bought at drug stores. These remedies are labeled with deceiving statements such as "Throw away your glasses," "A reliable relief for sore, red, inflamed, and itching lids," "Eye tonic," and the like. Patent medicines do harm in at least two ways: (1) they do not cure or relieve the diseases which their labels claim to relieve, and (2) they too frequently cause people who try them to put off consulting an eye specialist until it is too late to be cured.

Self-test on Problem XXVII–A. (*Do not write in the book.*) **1.** Lenses are designed to make practical uses of the *reflection* of light.

2. The lens of the eye is a *concave* lens.

3. The image thrown upon the retina of the eye or upon the plate or film in a camera is *inverted*.

4. When an object is brought closer to the eye, the lens becomes *thinner*.

[1] The American Medical Association, 535 North Dearborn Street, Chicago, Illinois, will furnish reliable information concerning patent medicines and healing devices of many kinds.

5. The image of an object one hundred feet from a convex lens is *smaller* than the image of the same object two hundred feet from the same lens.

6. State two reasons why patent medicines for eye troubles may do harm.

7. Write the words *Camera* and *Eye* as below. Under "Camera" write the names of five parts of the camera and in the blank opposite each under "Eye" write the corresponding feature of the eye:

Camera	Eye
(?)	(?)
(?)	(?)
(?)	(?)
(?)	(?)
(?)	(?)

Problem XXVII–B · What are the Construction and Functions of Some Common Optical[1] Instruments?

Learning to use refraction. Primitive man knew that in order to spear a fish he must aim below the spot where the fish appeared to be in the water (Fig. 312, p. 462). Thus he took refraction into account without knowing anything about refraction itself. During perhaps the last three thousand years men have begun to learn to make optical instruments that enable them to *use* refraction in many helpful and pleasant ways.

Eyeglasses. The commonest optical instruments are eyeglasses or spectacles. These are used to correct defects in vision. In a normal eye the image falls exactly upon the retina (Fig. 331, *A*). Few people, however, have perfect, or normal, eyes. The most common defects of vision are nearsightedness, farsightedness, and astigmatism. The eyeball of the nearsighted eye is too long for the thickness of the lens, with the result that the image falls in front of the retina (Fig. 331, *B*). Nearsightedness can usually be corrected by means of concave glasses. These spread the light rays, causing them to focus farther from the lens, on the retina (Fig. 331, *C*). The eyeball of the farsighted eye is too short

[1] *Optical* (op'ti kl): having to do with the sight, or vision.

for the thickness of the lens. The result is that the image falls behind the retina (Fig. 331, *D*). This defect is usually corrected with convex lenses. These lenses cause the light rays to focus nearer the lens, on the retina (Fig. 331, *E*). In the astigmatic eye the curved surfaces of the eyeball or of the lens are slightly uneven. The result is an imperfect image somewhat like that seen in the bowl of a spoon. This defect is corrected by specially ground lenses, unequally thick, and curving differently at different points.

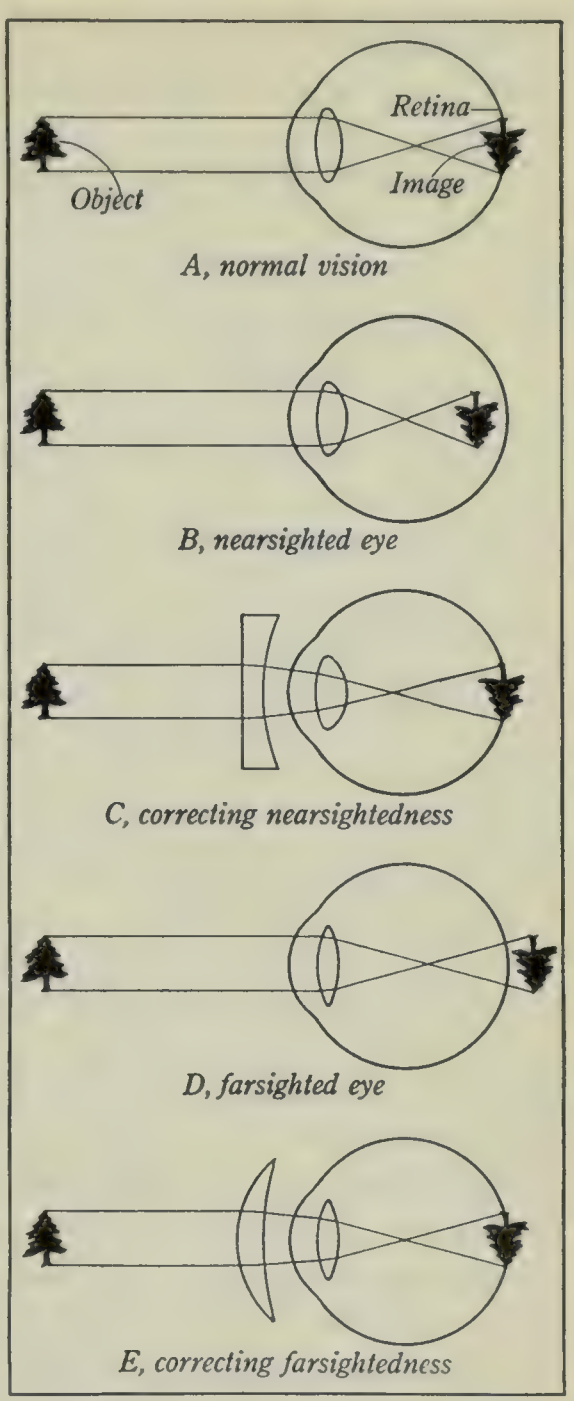


FIG. 331. Correcting defects in vision. How could you determine by looking through a spectacle lens whether it is concave or convex?

Complex optical instruments. Many of the great discoveries of modern science have been made with the use of optical instruments. Among the most important of these instruments are the microscope and the telescope. The microscope is used to study objects which are too small to be seen with the naked eye (Fig. 4, *B*, p. 7). The telescope is used to study huge objects, such as the stars and planets, which are too far away to be seen clearly with the naked eye. A simple microscope is a convex lens (a reading glass, for example) held close to the object. A compound microscope has two thick convex lenses so arranged that the second lens magnifies the image which the first one makes (Fig. 332).

Small telescopes and even some of the fairly large astronomical telescopes contain two convex lenses, one thin and the other thick. Such telescopes are known as refraction or refracting telescopes. The thin lens, in the front of the telescope, gives an image of a star. The thick lens, in the other end, gives a magnified image of the first image. The largest telescopes have a convex lens in the front end and a concave mirror in place of the convex lens at the rear end. Such telescopes are known as reflecting telescopes.

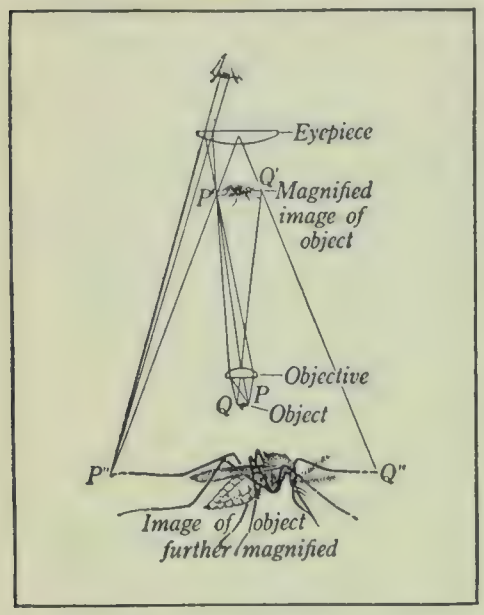


FIG. 332. In a compound microscope you see an image of an image. Explain this. **Special Report:** The invention of the microscope

Opera glasses are more convenient than telescopes for many purposes, because they give images right side up and because they are small and easily carried. The opera glass has a convex lens in front and a concave lens in the end through which the eye looks. Field glasses, or binoculars, have both convex lenses (usually three) and prisms (usually two). The prisms, which are of the general type of those used in the project on page 478, serve to turn the image right side up.

***Making images permanent.** Photographs are produced by transforming light energy into chemical energy. When the lens refracts the image upon the plate of the camera, the light energy acts upon the compounds of silver on the film in such a way as to leave the image on the film. You cannot see the image on the film until the film is developed. When the film is developed later, the image is made permanent by the action of other chemicals. The film is then a negative; that is, its lights and shadows are exactly the reverse of those in the scene represented in the negative. When the negative is placed over special paper, and light is allowed to pass through the negative to the paper, the light produces chemical changes on the paper which print the image of the negative on the paper. When the print is developed, we have the finished

photograph, or positive; that is, the relations of lights and shadows are the same as in the scene which the photograph represents. The photographs in this book are reproductions[1] of positives.

Motion pictures. Forty years ago very few people had even heard of a motion, or moving, picture. Nobody who saw the earliest moving-picture "shows" would have dreamed that in so short a time people would be taking their own moving pictures and showing them in their homes.

"Moving" pictures do not really move at all. They only seem to move. The reason is this: The moving-picture camera is so built that it can take about sixteen pictures a second on a long celluloid film. Of course the scene that is being photographed cannot change much in one sixteenth of a second. Consequently each picture is only slightly different from the one ahead of it. When the film is thrown on the screen at the rate of sixteen pictures per second, the image of one picture does not have time to fade from the retina of the eye before the image of the next picture strikes the retina. Therefore the successive images blend into each other so that we are not conscious that we are seeing separate pictures.

Talking pictures. The first talking pictures were introduced about twenty-five years ago. These consisted merely of phonograph records which were made at the same time the moving pictures were taken. The records were then played while the pictures were being shown. There was no way of making the sound start at the right time to agree with the pictures. The results were therefore so unsatisfactory that this type of talking pictures was soon withdrawn.

The modern talking pictures became possible when the problem of exact agreement of the sound with the action had been solved. In one type of sound recorder a beam of light is caused to vary in brightness in accordance with the changes in sound. This beam is directed through a narrow shutter upon a celluloid photographic film. The sound film, which is the photograph of the varying light beam, is printed along the margin of the picture film (Fig. 333).

[1] *Reproduce* (re pro duce′): to produce again, to copy. *Reproduction* (re-pro duk′shun): the act of reproducing, or a copy.

In reproducing the sound the recording process is reversed. A beam of light is focused on the sound film. This beam varies in brightness just as the beam was made to vary by the sound as it was recorded. This beam of light is thrown upon a photoelectric cell (Fig. 304, p. 451). The variations in the strength of the light beam cause variations in the electric current through the cell. This varying current is amplified (increased in volume) and sent through loud-speakers placed behind the moving-picture screen.

FIG. 333. A section of sound-motion-picture film. Two types of sound records are shown here: *A*, varying density, and *B*, varying width.

Special Report: The invention of motion pictures

The spectroscope. The spectroscope is an instrument of great importance in science, especially in astronomy and chemistry. It makes use of the fact that a prism will separate light into the different colors which compose it (Fig. 334). Whenever an incandescent solid or liquid body is looked at through the spectroscope, all the colors of the rainbow are seen in one continuous band, with violet at one end and red at the other and with all the other colors in their proper order between. Whenever an incandescent gas or vapor is looked at through the spectroscope, however, one or more color lines are seen instead of a complete band of colors. These lines are always exactly the same and are always in exactly the same position for any given substance. Furthermore, no two substances ever have exactly the same color lines. Therefore chemists and physicists heat a substance until it becomes an incandescent gas. By then observ-

ing it through the spectroscope, and by noting the colors, positions, and widths of the various color bands which they see, they are able to tell the elements of which the substance is composed.

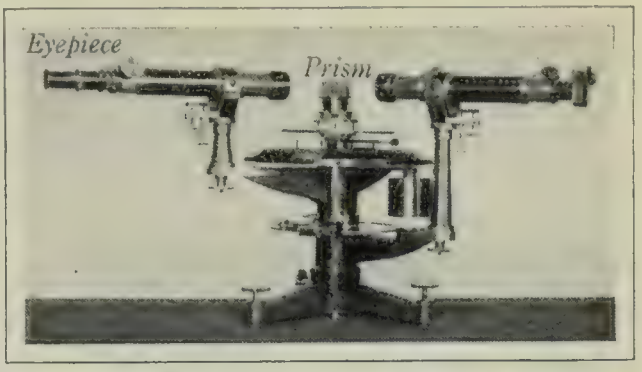


FIG. 334. A spectroscope. **Special Report:** The discovery of helium. (Consult a textbook of chemistry or an encyclopedia)

If between the spectroscope and the source of the light there is a gas or vapor, the spectroscope shows dark lines in the same places in which bright lines are seen when this gas or vapor is made incandescent and observed through the spectroscope. Hence astronomers look through their spectroscopes at the sun and the other stars and, by noting the number and positions of the black lines, are able to learn many of the chemical substances which compose the stars. By means of the spectroscope astronomers are also able to determine whether certain stars are moving toward the earth or away from it and how fast they are traveling.

Self-test on Problem XXVII–B. (*Do not write in the book.*) **1.** With nearsighted eyes the images fall *behind* the retina. Nearsighted vision is therefore corrected with *concave* lenses.

2. With farsighted eyes the images fall *behind* the retina. Farsighted vision is therefore corrected with *convex* lenses.

3. Refracting telescopes and compound microscopes have each *two concave* lenses.

4. A large astronomical telescope has a *concave* lens in front and a *convex* lens in the end through which the eye looks.

5. In taking photographs light energy is transformed into (1) electrical energy; (2) chemical energy; (3) mechanical energy; (4) heat energy; (5) sound.

6. In taking photographs light energy acts upon compounds of (1) iron; (2) aluminum; (3) silver; (4) lead; (5) tin.

7. The images on a moving-picture screen *seldom* move.

8. In a *telescope* the light is refracted through a prism.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why do people close their eyelids in bright light?

2. Why do one's eyes sometimes hurt when one comes into a bright light from the darkness?

Project. To make a simple telescope. Fig. 335 shows a telescope made by a girl who was studying general science. You can make one like it very easily. Place a thin convex lens in a lens holder near the end of a meter stick. Place a thick convex lens in another lens holder near the other end of the stick. Aim the "telescope" out of the window at some distant object, such as a house or a tree. As you move the thick lens slowly toward the thin lens, keep your eye close to it until you see the object clearly through both lenses. Turn the telescope end for end so that you look through the thin lens toward the thick one. Can you see the distant object through the lenses now? Is the image in the telescope right side up or inverted?

FIG. 335. A homemade telescope. **Special Report:** The accidental discovery of how a telescope could be made

Special Reports. 1. How does the iris of a cat's eye differ from the iris in your eye?

2. Examine a camera and find the purpose of each part.

3. What is color blindness?

4. Color-blind men are not allowed to become railroad engineers. Why?

5. What is the story of Galileo and his telescope?

6. How are slow-motion pictures made?

7. Make a study of patent medicines sold for eye troubles. Find out from the American Medical Association the truth about these medicines.

8. Describe completely the developing and printing of photographs.

Books for Reference

How to Make Good Pictures. Eastman Kodak Co., Rochester, N.Y.

LITTLE, W. S. Practical Amateur Photography. Little, Brown & Company, Boston.

LUBSCHEZ, B. I. Story of the Motion Picture. D. Van Nostrand Company, New York.

UNIT XI · *The Use of Energy in Transportation*

PROBLEMS DISCUSSED IN THIS UNIT

Have you ever stopped to think of the meaning of the word *homemade*? Can you name half a dozen things which you know were made — every part of them — entirely in your home? How many things can you see about you now which were made entirely in your town? It is hard to think of anything of which at least part was not brought here from somewhere else. But if it were not for transportation, everything would have to be homemade.

Two hundred years ago travel and transportation of goods from one part of this country to another were difficult (Fig. 336). People traveled and carried their goods by stagecoach and wagon where the roads were good enough to permit of this, by horseback where there were only sufficiently good trails, and on foot where there were not even good trails. Travel and commerce by water were carried on by sailboat, rowboat, or canoe. Travel and transportation by steamboat, train, automobile, or airplane were then unknown.

Progress in transportation, however, like progess in everything else, depends upon progress in science. After many centuries of patient experimenting on the part of thousands of scientists, the practical steam engine, gasoline engine, and electric motor we now know were brought to their present stage of efficiency. These three great inventions make modern transportation possible. They drive great ships, locomotives which are able to pull a hundred or more cars, automobiles and trucks, airplanes and dirigibles, and electric locomotives and cars. This unit will discuss these problems:

What are some important applications of science to transportation on land?

What are some important applications of science to transportation on water?

What are some important applications of science to transportation in the air?

Transportation Then and Now

WHAT fun it would be if you could take these children into your home! How wonderful many things common enough to you would be to them!

"These? Oh, these are sardines. They came from Norway in cans. (You would have to show them the cans before they would know what you meant.) This silk dress? The silk came from Japan, but the dress was made in Chicago. I've been there. It's only about five hundred miles from here. Five hundred miles? Why, that isn't far. What? You've never been ten miles

FIG. 336. Transportation in pioneer days. Special Reports: The Pony Express. How freight was transported from the Eastern states, or from eastern to western Canada, before there were railroads. (Consult history textbooks)

away from home in all your life! Yes, almost everything we have came from far away somewhere. Why we couldn't *live* if we could have only the things we could get here! Do you have to find, or make, or raise almost everything you have, for yourself, or go without? I don't see how you get along at all!

"How did these things get here? Why, by steamer, by train, by automobile truck, by airplane—What's that? You don't know what I'm talking about? Haven't you ever seen—Oh, no, of course you haven't. No, I think none of these things were brought here on horseback. Did my father carry these things here on his back? Why, no, of course not—."

Chapter XXVIII · Moving People and Goods about the Earth

Questions this Chapter Answers

How are a steam engine, a gasoline engine, and a Diesel engine constructed, and how does each operate?
How is heat energy removed from an automobile engine?
How is an automobile made to move?
How does an automobile use electrical energy?
How are modern roads and bridges constructed?
Why do bodies float?
What keeps objects upright?
How were modern airships developed?
How do balloons, dirigibles, and airplanes rise and remain in the air?
What are the characteristics of modern types of airplanes?

Problem XXVIII–A · What are Some Important Applications of Science to Transportation on Land?

***The steam engine.** The earliest steam engines were stationary engines. These preceded the traveling steam engines (Fig. 337) by at least a hundred years. The steam engine transforms the potential energy of the fuel into kinetic energy. When water is changed to steam, it expands so much that it takes up about sixteen hundred times as much space as it did before. Thus a cubic inch of water will make nearly a cubic foot of steam. The energy of the expanding steam can be made to do work.

***How a steam engine operates.** In the steam engine the expanding steam is made to push the piston back and forth (Fig. 338). The steam from the boiler enters the steam chest. A rod from the axle of the flywheel pushes the slide valve back and forth as the flywheel turns. When the sliding valve is in the position shown in Fig. 338, *A*, the steam from the steam chest passes into the cylinder on the right side, forcing the piston toward the left. At the same time the used, or spent, steam on the left side of the piston is forced out through the exhaust. By the time the piston

Fig. 337. From primitive to modern transportation. How many other means of transportation by land can you write in three minutes?

has reached the end of the stroke toward the left, the slide valve has moved over to the right side of the steam chest (Fig. 338, *B*).

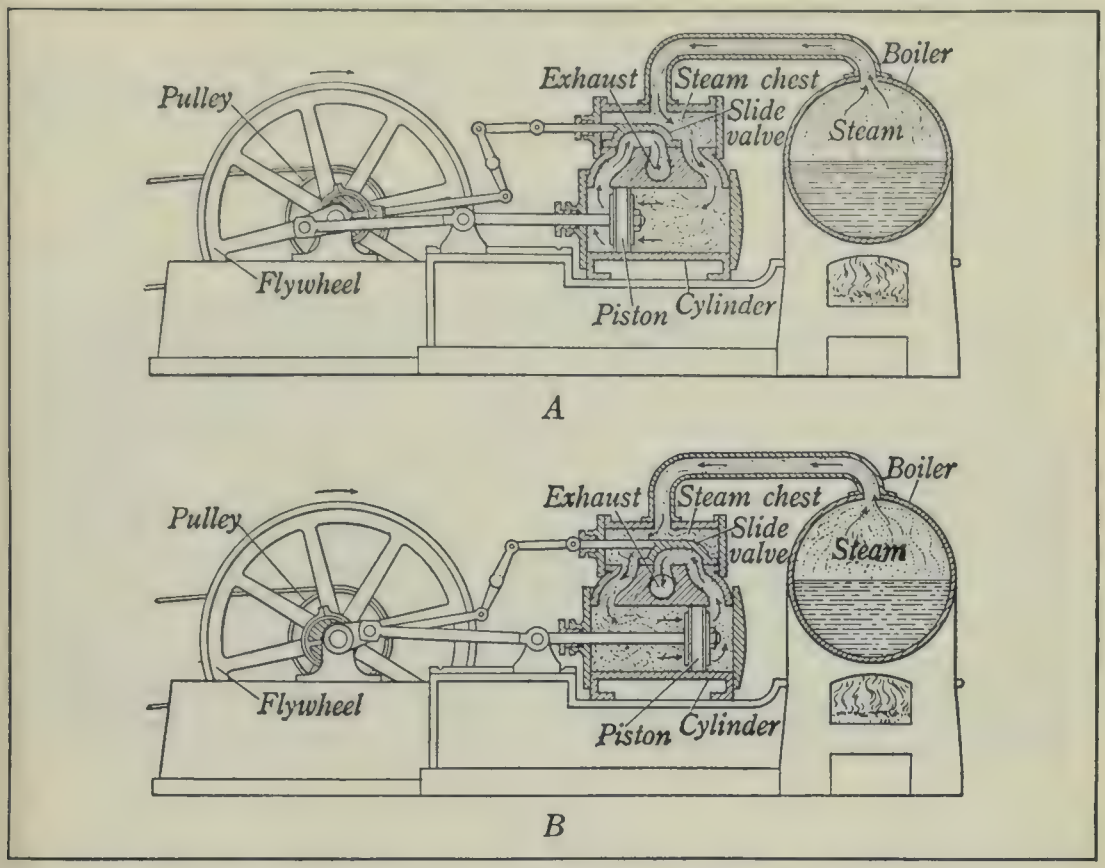


FIG. 338. Diagram of the working parts of a steam engine. A belt over the pulley turns the machinery which the engine is to run. After reading the explanations can you explain these diagrams?

The left-hand passage is then open between the steam chest and the cylinder. The right-hand passage connects the cylinder with the exhaust. The steam from the steam chest may now enter the left side of the cylinder. The steam pushes the piston to the right, forcing the spent steam in the right end of the cylinder out through the exhaust. By the time the piston stroke to the right is completed, the slide valve has again moved to the left side of the steam chest and the cycle just described begins again.

*The piston is attached to the flywheel, which it turns as it moves back and forth. The flywheel is heavy and therefore has great inertia. This inertia keeps the engine moving steadily and smoothly, even though the steam pressure against the cylinder should vary slightly.

Early Progress toward Steam Transportation

THE STEAM engine, like most other inventions, is the product of several men of genius, but three especially,—Newcomen, Watt, and Stephenson. THOMAS NEWCOMEN (1663–1729), an English blacksmith, was one of the first men to see that machinery could be driven by steam power. He took the few things that had been discovered about steam power before his time and, with the help of his assistant, John Cawley, and of Thomas Savery, a military

FIG. 339. Stephenson's *Rocket*. Exercise on Scientific Attitudes: What scientific attitudes (pp. 12 and 13) are here illustrated by the work of Newcomen, Watt, and Stephenson?

engineer, constructed what is now known as the "atmospheric steam engine." This engine was used to pump water from the deep mines in England.

*JAMES WATT (1736–1819), a Scottish engineer, was an instrument-maker at the University of Glasgow when a model of Newcomen's engine was one day brought to him for repair. He worked for two years trying to improve it. Finally he invented the modern condensing steam engine. The first important use of Watt's engine was lifting coal from the mines and hauling it by stationary engines from the mines to the shipping point.

*GEORGE STEPHENSON (1781–1848) was an English engineer who had worked in the mines from boyhood. He was interested in the inventions of Watt and other men, and learned to read when he was eighteen years old in order to find out more about them. The problem of transportation interested him so much that he made over Watt's invention into a "traveling engine," the "great grandfather" of our modern locomotive. He himself lived to see many railways in operation as the direct result of these inventions.

The steam turbine. The latest development of the steam engine is the steam turbine. It operates in much the same way as a water turbine except that steam instead of water is forced at great pressure against the blades. The steam turbine is used chiefly in large power plants. It is also used in many of the great ocean liners.

Stationary and traveling steam engines. The stationary steam engine is of great importance in industry because it is used to run sawmills, to run dynamos for generating power, to run machinery in factories, and for many similar purposes. The traveling steam engine, or locomotive, is of great importance in transportation. The locomotive operates in exactly the same way as a stationary steam engine except that instead of a flywheel the piston turns great drive wheels which run on a track.

The railroad locomotive was largely responsible for the rapid settlement and development of this country. It is still of major value in the civilized world. The story of its development from Stephenson's *Rocket* (Fig. 339) to the huge and powerful engines of today is one of the most interesting chapters in the history of science (Fig. 340).

***The gas engine.** The gasoline engine, or gas engine, transforms chemical energy into mechanical energy. In the gas engine the energy of exploding gasoline vapor, instead of expanding steam, moves the piston. Gasoline vapor will not explode in a vacuum. It must have oxygen for combustion just as does any other fuel. The liquid gasoline is rapidly changed to a vapor and mixed in the carburetor (Fig. 341) with enough air to give the amount of oxygen necessary to make the best explosion. The explosive mixture of gasoline vapor and oxygen goes from the carburetor into the engine.

Fig. 342 will help you to understand the four stages, or strokes, in the action of a gas engine.

*1. *The intake stroke (downward).* When the engine is started, the piston moves downward, causing a partial vacuum in the cylinder. At the same instant the intake valve opens. The air pressure outside forces air through the carburetor, carrying the explosive mixture of gasoline vapor and air from the carburetor into the cylinder.

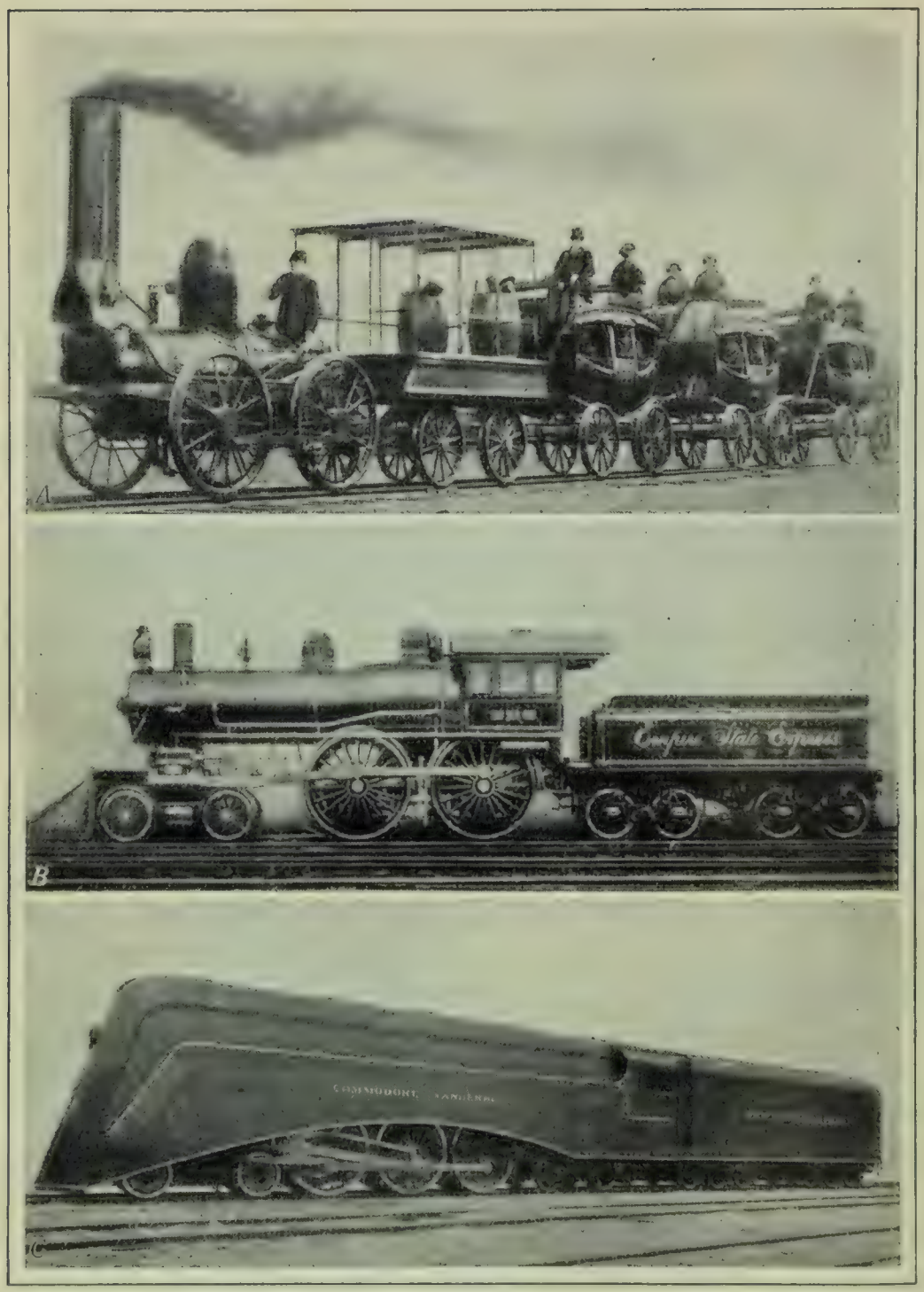


FIG. 340. Three stages in the development of the steam locomotive. What advantages do you think each type has over the preceding one?

*2. *The compression stroke (upward).* As soon as the piston starts upward in the compression stroke, the intake valve closes. The crankshaft is attached to the flywheel, which is heavy so as to have great inertia. After the flywheel has been started, its inertia keeps it turning and thus forces the piston upward, compressing the mixture of air and gasoline vapor.

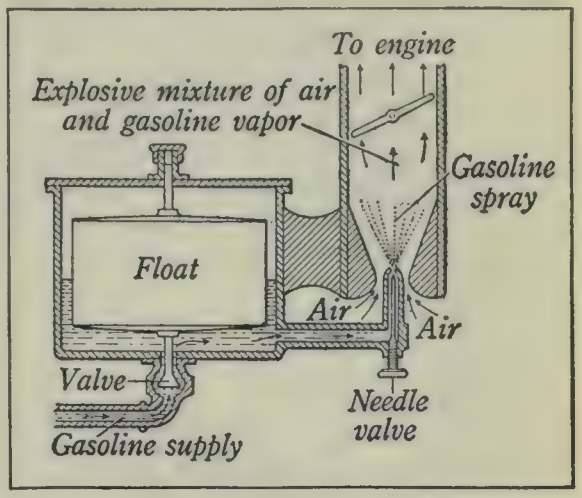


FIG. 341. Diagram of a carburetor. Explain from the figure how the carburetor operates

*3. *The power stroke (downward).* Just before the piston reaches the top of the compression stroke an electric spark jumps between the points of the spark plug. This spark explodes the mixture of air and gasoline. The energy of this explosion pushes the piston downward with great force.

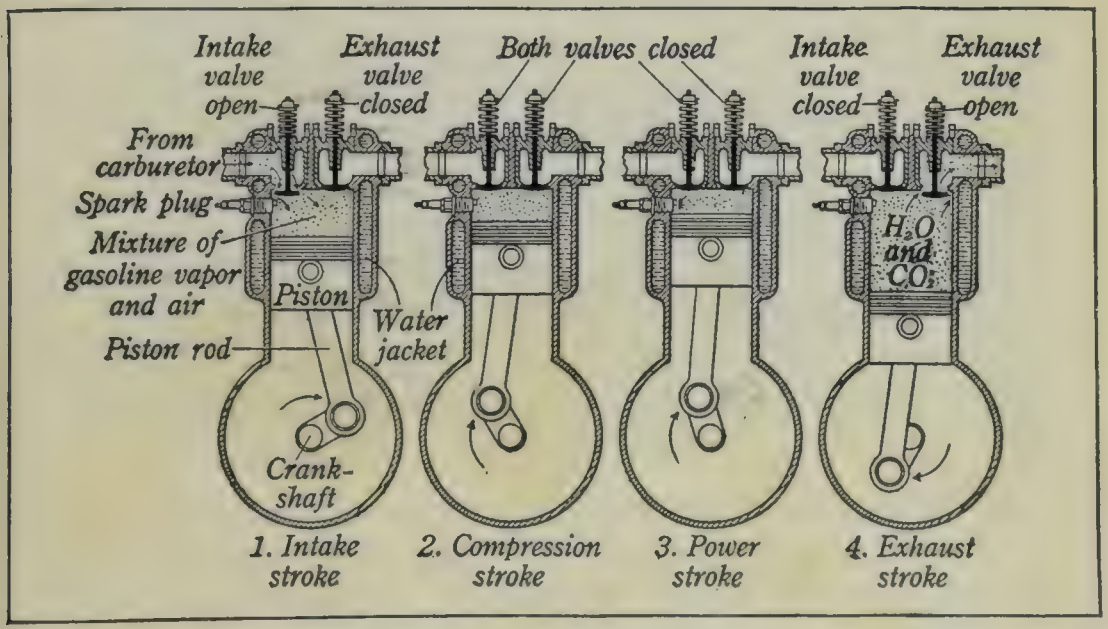


FIG. 342. Diagrams showing the four piston strokes of a gas engine. Why are gas engines, rather than steam engines, used in automobiles and airplanes?

*4. *The exhaust stroke (upward).* The inertia of the flywheel causes the wheel to keep turning and pushes the piston upward

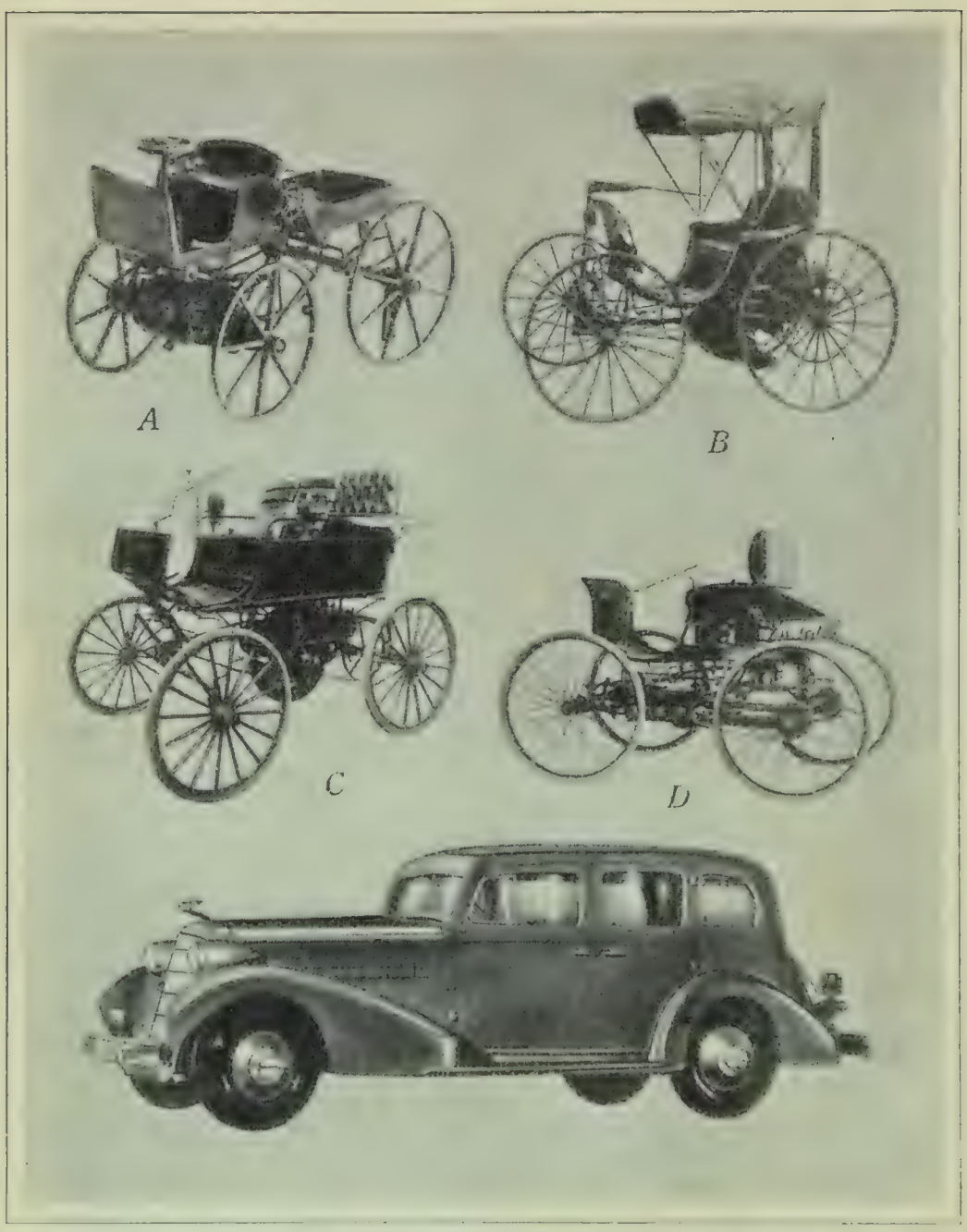


FIG. 343. The earliest types of automobiles and a modern automobile. *A*, Selden; *B*, Haynes; *C*, Duryea; *D*, Packard. How many power strokes does an eight-cylinder engine deliver during each complete revolution of the flywheel?

again. But just as the piston starts upward the exhaust valve opens so that the piston can push the water vapor, carbon dioxide, and other products of the combustion of the gasoline vapor out through the exhaust pipe. The inertia of the flywheel again carries

the piston downward, the intake valve opens, and the four strokes in the cycle of the gasoline engine are repeated.

***How frequent are the power strokes?** In each cylinder there is only one explosion for every two complete revolutions of the flywheel. The flywheel continues to revolve between explosions because of its inertia. In a four-cylinder automobile engine the pistons are so adjusted that they take turns in giving their power strokes. Thus while the first cylinder is on the intake stroke the second is on the compression stroke, the third is on the power stroke, and the fourth is on the exhaust stroke. By this arrangement one of the four cylinders is delivering a power stroke as often as the flywheel makes a half revolution. The six-cylinder engine delivers a power stroke from one of its cylinders every time the flywheel makes one third of a revolution.

The gasoline engine is of great importance and value in transportation because it is used to drive automobiles (Fig. 343), airships, and boats. It is also widely used in industry to run small power plants, to run pumps, and for many similar purposes.

The Diesel engine. The Diesel engine, burning a variety of oils instead of gasoline, is rapidly taking the place of other types of engines for many purposes. This engine operates much like the gas engine. Air is admitted to the cylinder on the down stroke of the piston. We have learned that air is heated by compression. This air is compressed so strongly on the upstroke that the temperature is raised to practically 1000° F. Just before the piston reaches the top of its stroke the fuel oil is sprayed into the cylinder. The high temperature of the compressed air ignites it. The oil burns without exploding, forcing the piston down, just as in the power stroke of the gas engine. On the next upstroke the valve opens, allowing the gases resulting from the combustion to be forced out through the same pipe through which the air entered at the beginning of the cycle.

Diesel engines are being used in some of the new great locomotives, in some steamships, in submarines, and to some extent in airplanes.

How is heat energy removed from an automobile engine? We have already learned that an automobile is moved by the energy obtained from the explosion of gasoline in the cylinders. Not all

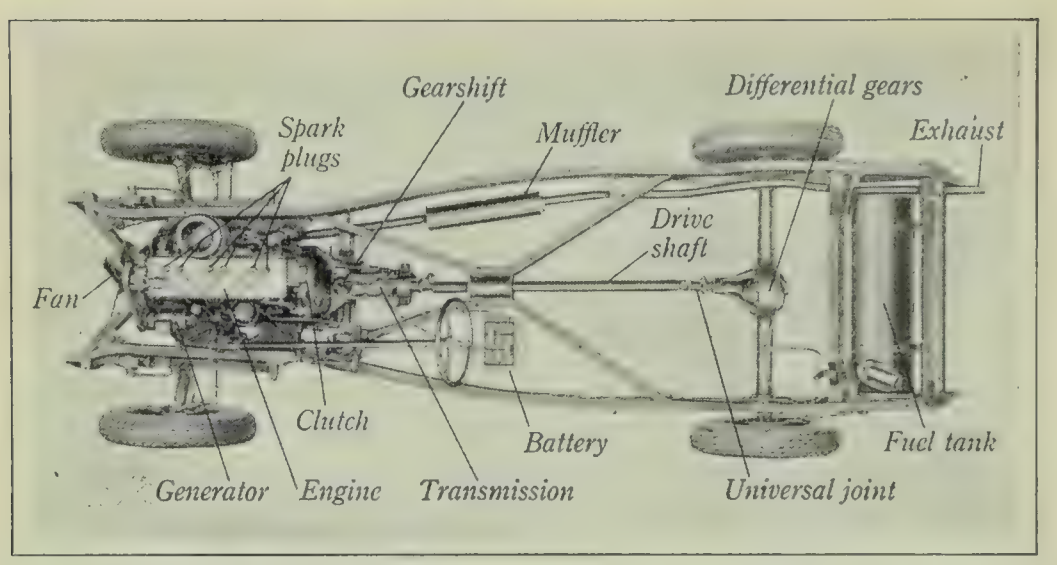


FIG. 344. Diagram showing the working parts of an automobile. How many different changes of energy from one form to another occur in an automobile?

the energy, however, is transformed into the kinetic energy of the moving automobile. Some is transformed into the electrical energy needed for various purposes in the automobile. Much of the potential energy of the gasoline is transformed into heat energy. Most of this heat energy is not wanted; in fact, it would do harm to the engine unless it could be removed. It passes through the steel walls of the cylinders by conduction. Part of it radiates away, most of the rest is absorbed by the water in the water jacket (Fig. 141, p. 207), and practically all that remains is absorbed by the cool air which passes over the engine. Hence the convection currents would cause a slow circulation of water from the engine through the radiator and back, but more rapid movement of the water is needed. The water is pumped so that it circulates through the radiator, where it gives up heat energy to the cool air which is caused to enter through the meshes in the radiator by the action of the fan.

How is an automobile made to move? The mechanical, or kinetic, energy of the moving pistons causes the crankshaft to revolve. A heavy flywheel is attached to the rear end of the crankshaft. The flywheel cannot, of course, be connected directly with the rear wheels of the car. The latter cannot instantly be set in motion because of its inertia. The clutch serves therefore, when desired, either to deliver the energy from the flywheel

to the differential gears (Fig. 344) or to permit the engine to run without turning the gears. Also a clutch and the transmission are needed, because a gas engine cannot deliver its maximum power at low speeds. A clutch consists of a disk of metal faced on each side with a clothlike material woven from asbestos and very small brass wire. The clutch makes a firm contact with the face of the flywheel when the clutch pedal is up. The clutch disk then turns with the flywheel, transferring the kinetic energy of the revolving flywheel through the clutch shaft to the transmission gears. When the clutch pedal is pressed down, however, the clutch disk moves back from the face of the flywheel and therefore does not turn the transmission gears. The transmission gears are arranged to slide back and forth, engaging in turn with other gears on a countershaft. When the transmission is in neutral, no energy is transmitted by the transmission gears to the drive shaft. The transmission gears are shifted into low as the car starts. The driving shaft is then turning at a much slower speed than the crankshaft. As the car gains speed, the gears are shifted into intermediate, and then into high. The drive shaft and the crankshaft are then rotating at the same speed. Since the rear axle is at right angles to the drive shaft, the motion of the drive shaft must be turned at a right angle in order to turn the rear wheels. This change of motion is accomplished by the differential gears. The differential gears also permit one wheel to rotate faster than the other. If this were not possible, one rear wheel would always skid or slide on every turn, because the wheel on the inside of a turn moves a shorter distance than the wheel on the outside.

How does the automobile use electrical energy? Each automobile carries its own powerhouse. The powerhouse consists of a storage battery and a small generator, which is run by the engine. When the engine is running, it generates enough current by running the generator to light the lamps, to furnish the electrical energy for the spark plugs (Fig. 345), and to charge the storage battery. When the engine is not running, the storage battery furnishes enough current to start the engine and to operate the lights and other electrical circuits.

Care of automobile storage batteries. Automobile storage cells require careful treatment. Enough distilled water should be

added from time to time so that the solution is never below the top of the plates. The solution should also be frequently tested

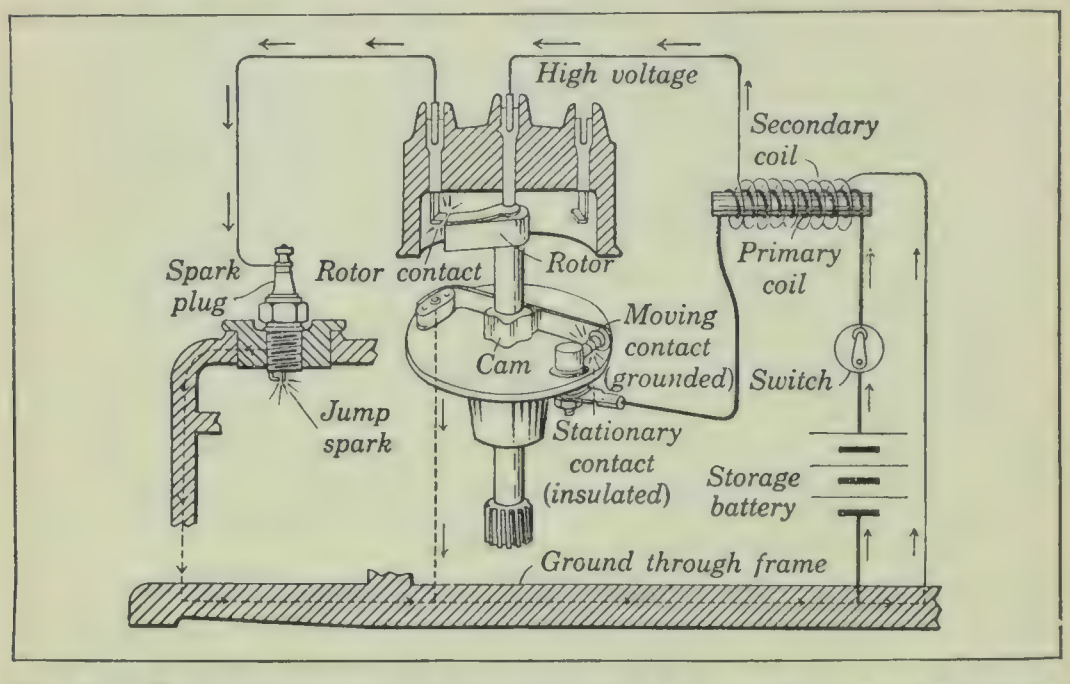


FIG. 345. The ignition system of an automobile.[1] **Special Report:** Explain the operation of the ignition system. (Consult a high-school textbook of physics)

with a battery tester to be sure that the cell is properly charged. A fully charged cell reads from 1270 to 1300 on the battery tester. This means that the specific gravity is from 1.27 to 1.30. The cell needs charging again when its reading with the tester is below 1150. If the cells test differently or if anything seems wrong with them, they need the attention of the expert at the battery station.

Improved roads. In early pioneer days all roads were narrow, winding, exceedingly rough and muddy. Even the turnpike roads, which were famous gravel roads forty years ago, would be considered poor roads today. The common use of the automobile made the improvement of roads necessary (Fig. 346). Today there are more than half a million miles of hard-surfaced roads in the United States and Canada.

How are modern roads constructed? Concrete roads are commonly made by putting a layer of concrete on a foundation of

[1] From Stewart, Cushing, and Towne's *Physics for Secondary Schools*.

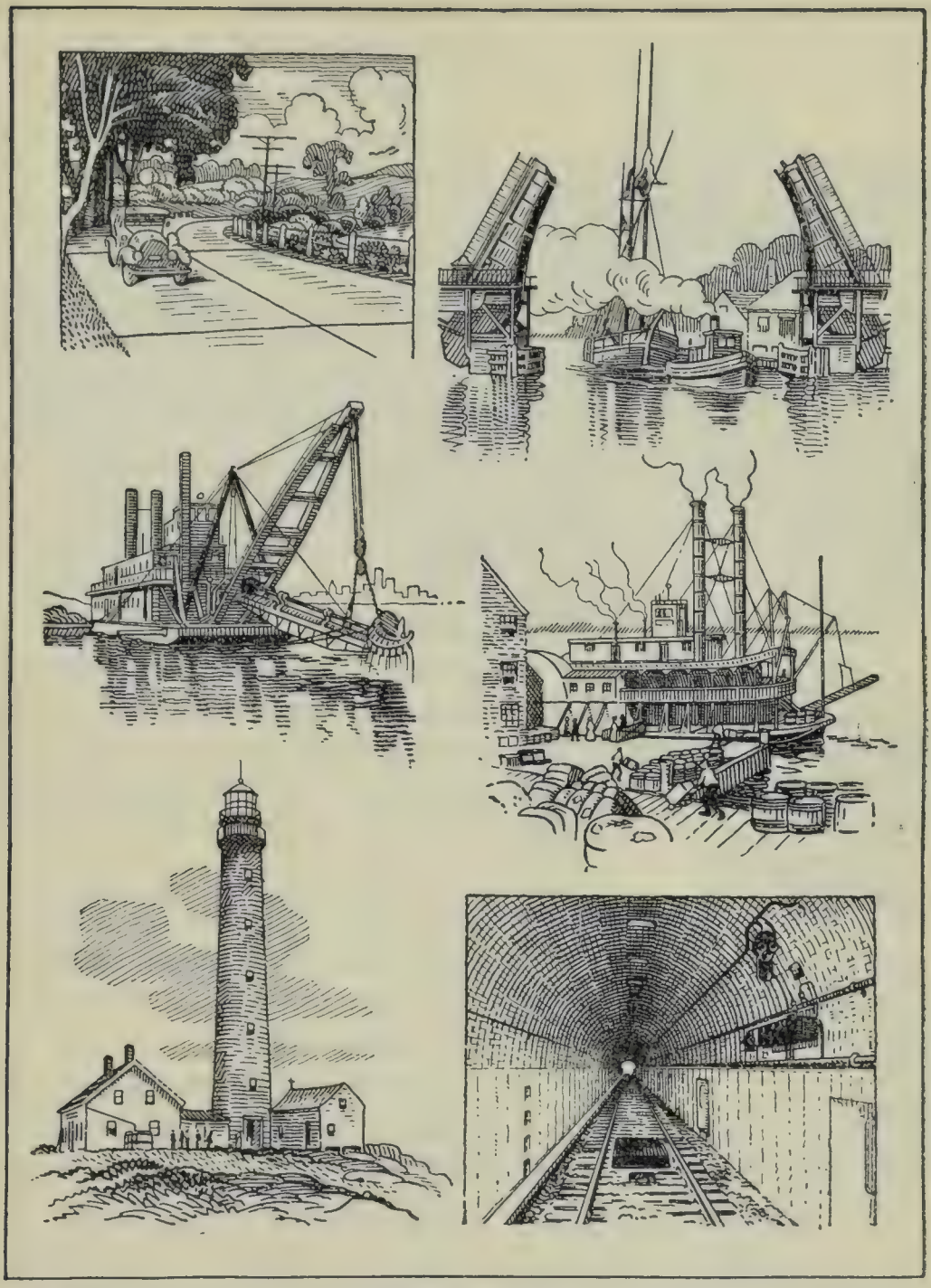


FIG. 346. In what ways do roads, drawbridges, dredges, levees, lighthouses, and tunnels aid transportation? How many other aids to transportation can you name?

crushed stone and surfacing it with cement. Such roads are expensive to build, but they last longest and afford a good grip to automobile tires. Macadam roads are made by putting down first a foundation of heavy stones, then layers of stone and crushed rock of decreasing size toward the top. The top covering is asphalt or tar. Such roads require frequent repairs and are slippery in wet or frosty weather. In some parts of the country brick highways are found fairly satisfactory. Concrete, brick, and macadam roadbeds, however, are frequently broken in winter by the freezing of water which has entered through cracks. The automobile has made necessary state, Federal, and Dominion commissions to give constant care to upkeep as well as construction of modern kinds of roads. Roads are built higher on the outside than on the inside of curves and often are made somewhat higher in the middle than at the sides. Why?

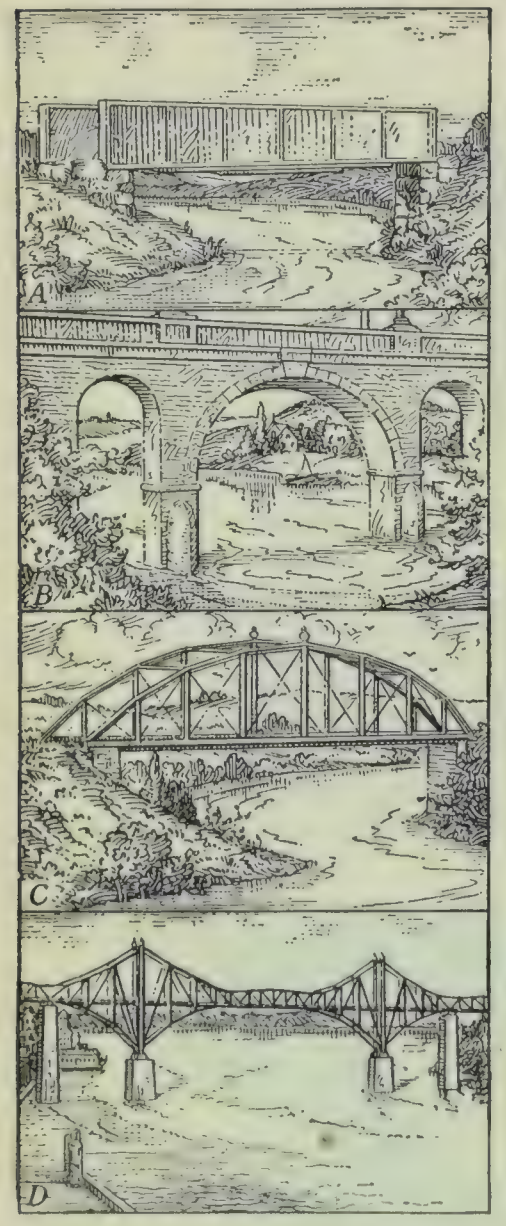


FIG. 347. Some types of bridges: *A*, girder; *B*, arch; *C*, truss; and *D*, cantilever. The girder is the earliest type of bridge. Can you see a reason for this?

Travel before there were any bridges. In the days of the covered wagon there were few or no bridges along the roads. The pioneers often had to go far out of their direct way in order to find fords by which to cross the rivers. They were often forced to build rafts or to float their wagons across the great rivers by lashing logs to the wheels. When the streams were high the travelers often had to wait for days or even weeks for a safe crossing.

Types of bridges. When the new country became settled, the first bridges were made of wood. The trunks of trees were used

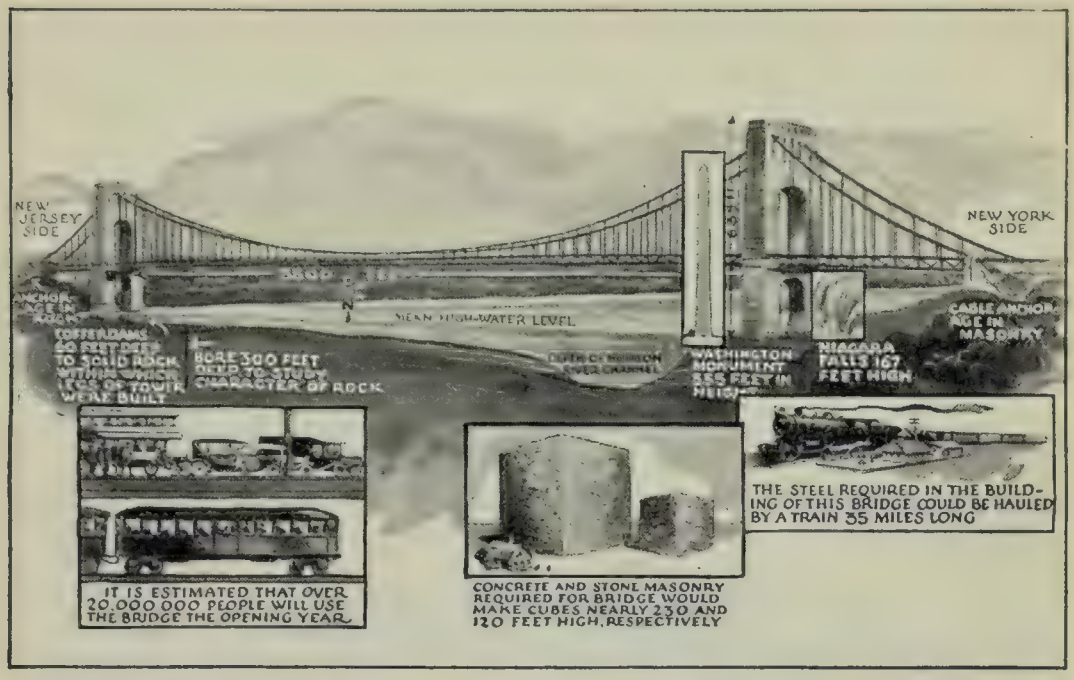

NEW JERSEY SIDE
NEW YORK SIDE
MEAN HIGH-WATER LEVEL
BORE 300 FEET DEEP TO STUDY CHARACTER OF ROCK
WASHINGTON MONUMENT 555 FEET IN HEIGHT
NIAGARA FALLS 167 FEET HIGH
IT IS ESTIMATED THAT OVER 20,000,000 PEOPLE WILL USE THE BRIDGE THE OPENING YEAR
CONCRETE AND STONE MASONRY REQUIRED FOR BRIDGE WOULD MAKE CUBES NEARLY 230 AND 120 FEET HIGH, RESPECTIVELY
THE STEEL REQUIRED IN THE BUILDING OF THIS BRIDGE COULD BE HAULED BY A TRAIN 35 MILES LONG

FIG. 348. The George Washington Bridge connecting New York City and New Jersey. This diagram was made from original drawings and plans several years before the bridge was built. **Exercise on Scientific Attitudes:** What scientific attitudes (pp. 12 and 13) did those who planned this bridge need to possess?

as girders (Fig. 347, *A*). Small tree trunks or thick planks were laid across these girders to make the roadway. Many bridges of pioneer days were made secure by means of wooden pegs instead of iron nails. In more recent times wooden bridges have mostly been replaced with bridges of several types made of steel and concrete. Common types are the girder, the arch, the truss, the cantilever (Fig. 347), and the suspension (Fig. 348). The girder is suitable only for short spans. The arch can be used for spans of somewhat more than two hundred feet. The cantilever and suspension types are most suitable for great spans. The cantilever type is so built that the parts on each side of each pier balance each other. The suspension bridge has its roadway suspended from great steel cables which are supported by great towers. Indeed, modern bridges demand much accurate scientific knowledge in their proper construction.

Some Early Steamboats

JOHN FITCH (1743–1798) successfully operated a passenger steamboat on the Delaware River in 1786. He even invented the engine which operated the sets of upright paddles which you see in the picture. Seventeen years before Fulton's *Clermont* made its historic trip up the Hudson, Fitch's third boat had run more than a thousand miles in regular trips up and down the Delaware. In 1796 Fitch built the first boat to be driven by a screw propeller.

FIG. 349. Fitch's first steamboat. Its speed was three miles per hour. Why would paddles be less effective than a side wheel or a stern wheel?

The United States has only lately recognized Fitch's genius, by setting aside $15,000 for a monument to him. Like many other great inventors, he died poor.

JAMES RUMSEY (1743–1792), also an American, was working upon a steamship at the same time as Fitch. He was given the sole rights to operate steamboats in Virginia, Maryland, and New York, just as Fitch was granted similar rights covering New Jersey, Pennsylvania, and Delaware.

WILLIAM SYMINGTON (1763–1831), a British inventor, constructed his steamboat, the *Charlotte Dundas*, in 1801–1802 in Scotland.

ROBERT FULTON (1765–1815) made his early experiments in France and returned to America to build his *Clermont* in 1807. Fulton never claimed to have invented the first steamboat, but only to have perfected the work which other men had begun. Fitch and the earlier inventors failed to make their boats succeed financially, but Fulton's boats were so successful that he built one after another. Before he died at the age of fifty, he had built seventeen steamboats, among them the first steam warship.

Exercise on Scientific Attitudes. What scientific attitudes (pp. 12 and 13) are illustrated by Fulton's work?

Self-test on Problem XXVIII–A. (*Do not write in the book.*) **1.** The steam engine transforms into *potential* energy the heat energy of burning fuel.

2. The flywheel of a steam engine or a gasoline engine keeps the motion steady because of its *force.*

3. Before the gasoline vapor will explode in the cylinders of a gas engine it must be mixed with *nitrogen.*

4. In the gas engine the mixture of gasoline vapor and air is first *expanded* before it is exploded.

5. In the gas engine the explosion occurs just *when* the piston reaches the top of the compression stroke.

6. The unwanted heat energy in an automobile engine is absorbed by cooler *air* and __(?)__.

7. Arrange the following parts of an automobile in the correct order to show how the mechanical energy of the engine is carried to the wheels: (1) transmission gears; (2) clutch shaft; (3) differential gears; (4) flywheel; (5) rear wheels; (6) drive shaft; (7) pistons of the engine; (8) clutch; (9) rear axle; (10) crankshaft.

8. Some of the *potential* energy in the gasoline is transformed into *electrical* energy in the automobile.

9. Concrete roads require more frequent repairs in climates where the winters are *mild* than in climates where the winters are *severe.*

10. A bridge engineer is planning to build a span five hundred feet in length. He will probably choose either the __(?)__ or the __(?)__ type.

Problem XXVIII–B · What are Some Important Applications of Science to Transportation on Water?

Modern water transportation and steel ships. Not long ago all vessels were made of wood (Fig. 349). Compared with our greatest modern liners and freighters, these vessels were small. When men learned to build ships of steel they were able to build them of much greater size (Fig. 350). But how is it possible for boats made of steel to float? Some of our greatest battleships wear on their sides steel armor more than a foot thick. Let us first find out why an object floats in water.

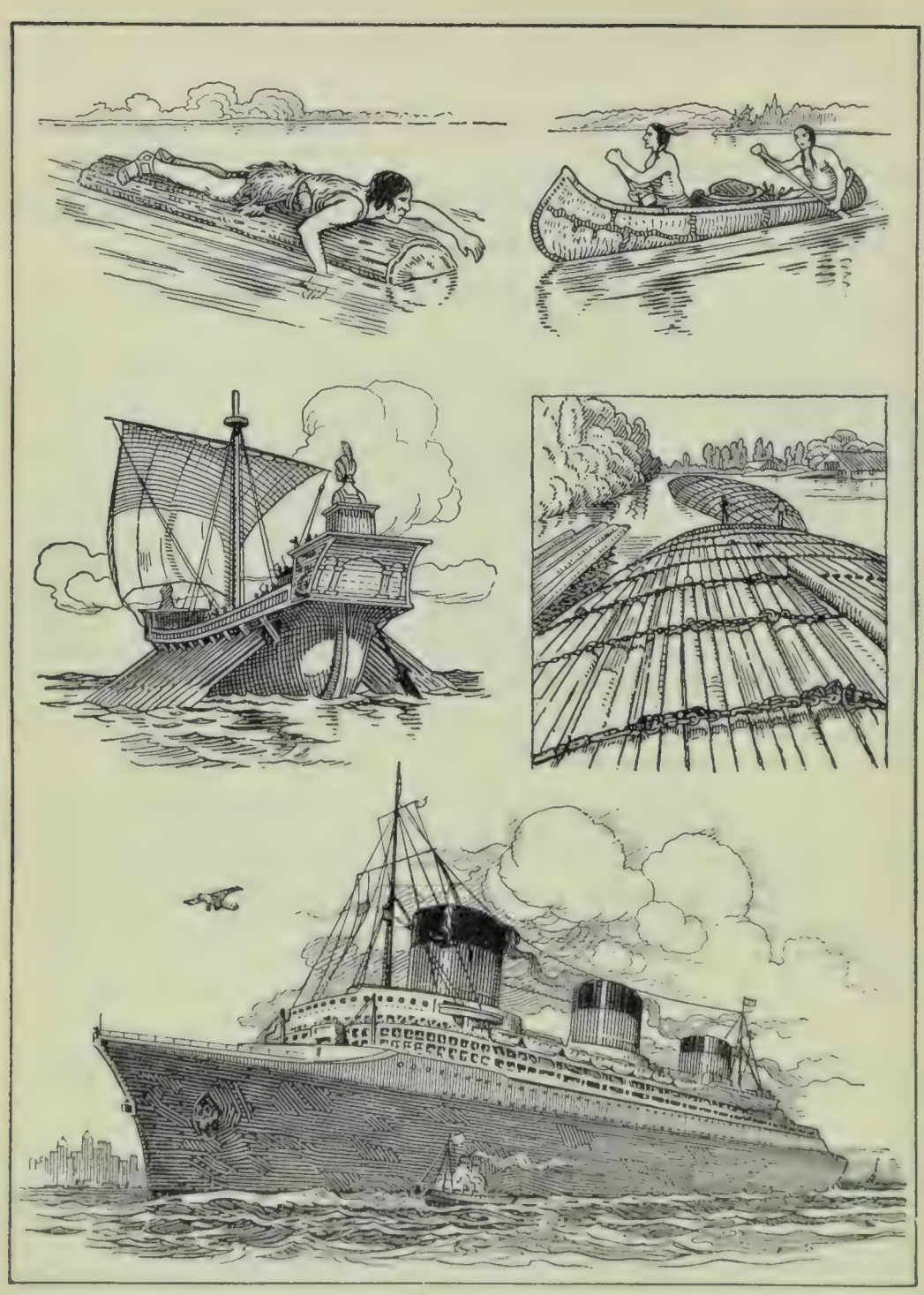


FIG. 350. From primitive to modern transportation on water. How many other examples of transportation by water can you name in three minutes?

Why do bodies float? ***Experiment 82.*** Does an object which sinks in water lose none of its weight, some of its weight, or all of it? Attach an iron or lead weight or a glass stopper by a string to a spring balance. Note its weight. Immerse the weight in water as in Fig. 351. How does its weight in water compare with its weight in air? Make a complete sentence answering the question at the beginning of this experiment.

Experiment 83. Does an object which floats in water lose none of its weight, some of its weight, or all of it? Attach a wooden block in place of the iron weight used in the preceding experiment. Note how much it weighs before you put the wood on the water. How much does it weigh when you float it? Make a complete sentence answering the question at the beginning of this experiment.

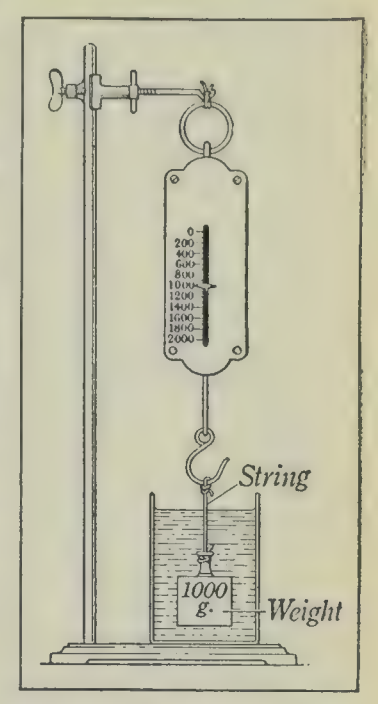


FIG. 351. **Weighing under water. Exercise on Scientific Method (Recognizing Errors in Procedures):** An error has purposely been made in this diagram. Can you perform the experiment and find the error?

*When a body is put into water, it displaces, or pushes aside, some of the water (Fig. 352). More than two thousand years ago Archimedes discovered that a body put into water loses a weight equal to the weight of the water which it displaces. If the weight of water which the body displaces equals the weight of the body itself, the body floats. If the weight of displaced water is less than that of the body, the body sinks. It is easy to understand why wood floats, because wood is less dense than water and has to sink only a little way in the water before it displaces the amount of water which weighs as much as it does. Fig. 353 illustrates these facts.

***Why do iron ships float?** It is not so easy, however, to understand why ships made of iron (which is denser than water) can float, because a lump of iron cannot displace enough water to weigh as much as it does. The following experiment will help you to understand why iron ships can float.

Experiment 84. Does a can displace more water than a lump of iron which has the same weight as the can or does it displace less? Weigh

an empty tomato can or other similar can. Select a pail or other vessel which is only a little larger than the can and fill it so full of water that some spills over. Place the can on the water. Does it float? The can is like an empty iron ship, because the can is made of iron. Does it displace any water? Now put a cargo of nails or stones in the can (ship) until it barely floats. Does the ship with its cargo displace more water than did the empty ship or does it displace less? Weigh the cargo. Can an iron ship carry a cargo which weighs more than the ship itself? Remove the can and its cargo from the water, but leave the water in the pail. Remove the cargo, dry the can, and pound it into a small lump. Have you changed the weight of the can? (If you are not sure, weigh the can.) Have you changed the volume of the can (that is, does it take up more or less space than before)? Put the lump of metal and all the cargo back into the pail of water. Do the metal and the cargo displace as much water as they did when the can contained the cargo? Answer with a complete sentence the question at the beginning of this experiment.

FIG. 352. This ship with everything on and in it weighs two thousand tons. Therefore it sinks down in the water until it displaces two thousand tons of water. The volume of displaced water is the same size and shape as the part of the ship under water. Notice how much greater the total volume of the ship is than the volume of displaced water. Can you explain why it is possible for a piece of iron or of lead to float in mercury? (Try this)

*When the iron is in the form of a lump, it cannot displace water enough to weigh as much as the lump does. But when it is in the form of a ship's hull, the same weight of iron has its volume increased many times. When the ship's hull sinks down in the water, it displaces just as much water as if the part below the water were solid iron. But most of the ship's volume is made up

of air, which is much less dense than the water. Consequently the vessel sinks just far enough to displace enough water to equal the weight of the ship and all its cargo.

Stability. If you have ever ridden in a canoe, you know that the canoe is almost certain to tip over if you stand up in it. But if you sit in the bottom, it is not hard to keep upright. The canoe is even less liable to tip over if you lie down in it. We know that the canoe is more stable (that is, less liable to turn over) if its passengers and cargo are as low as possible. In the same way automobile-makers put the heavier parts of the automobile as low as possible. With most of the weight nearer the ground the automobile has greater stability; that is, it is less liable to turn over when it turns corners quickly or when it skids. The cargo of a ship helps to keep the boat stable, because its weight is stored in the boat mostly below the water line. If the cargo were piled on the deck or were hung upon the masts, the boat would be almost certain to overturn when the wind blew or when the boat rolled on the waves. Ballast is often carried in the bottoms of ships to make them stable when they are traveling across the ocean without cargoes.

FIG. 353. How is it possible for the boy to float? Why is it easy for the boys to keep their noses above water when they swim? What would happen if all the boys got on the raft at once? Explain. How does the tire help the boy to float? Is it easier or harder for the boys when the stones are under water than when they are in the air? Explain

A body can be made more stable not only by putting the weight as low as possible but also by making the base of the body larger.

Thus we have chairs with four legs — one at each corner, instead of only one under the middle of the chair. We choose lamps with big bases rather than those with little bases. For the same reason rafts or barges are less liable to tip over than boats.

Self-test on Problem XXVIII–B. (*Do not write in the book.*) **1.** A life preserver enables the one who wears it to displace considerably *less* water without adding greatly to his total weight.

2. When a two-pound cork is forced below the surface of water, it displaces (1) considerably less than two pounds of water; (2) slightly less than two pounds; (3) exactly two pounds; (4) considerably more than two pounds; (5) slightly more than two pounds.

3. A great battleship displaces (1) slightly more than its weight of water; (2) slightly less than its weight of water; (3) much more than its weight of water; (4) much less than its weight of water; (5) a weight of water equal to its own weight.

4. The *broader* the base of an object and the *more* of its weight that is placed near its top, the *more* likely it is to tip over.

Problem XXVIII–C · What are Some Important Applications of Science to Transportation in the Air?

Early attempts to fly. It is to be expected that man's first ideas of human flight through the air should involve the use of wings. As early as 400 B.C. philosophers were discussing the possibilities of flying. You are no doubt familiar with the ancient myths of the winged Greek god, Mercury; the winged horse, Pegasus; the winged dragons of Medea; and the flights of Daedalus and Icarus. As scientific knowledge advanced, attempts were made to invent artificial wings to be attached to a man's arms and legs. It was even thought by some of the early scientists that it should be possible to invent wings with which a man could fly to the moon.

At the beginning of the sixteenth century an Italian alchemist[1] fell and broke his leg when he attempted to fly from the walls of a castle in Scotland to France. Other bold pioneers of aviation were injured or killed in attempts to fly with such wings. At about

[1] *Alchemist* (al'kem ist): one who tries to make gold from less valuable metals or who tries to make "the elixir of life."

this time Leonardo da Vinci, who was not only one of the greatest painters of all time but was also an engineer, architect, scientist, sculptor, and musician, designed artificial wings which included many scientific principles. It is even claimed by some writers that in the seventeenth century a man named Dante invented wings with which he actually flew. During the past few years a number of attempts have been made to fly with artificial wings from an airplane to the ground.

Balloons and dirigibles. The earliest suggestion of a balloon which would float in the air is credited to Roger Bacon, an English philosopher of the thirteenth century. The first successful balloon, however, was that invented by the Montgolfier brothers in 1783 (Fig. 354). It was a "fire balloon," that is, a balloon filled with smoke and hot air from a fire. The smoke and hot air of later fire balloons were supplied by a fire which burned in a large metal pan under the opening at the bottom of the balloon. The great danger from the fire, together with the relatively small lifting force of the smoke and hot air, soon caused this type of balloon to be abandoned. Modern balloons and dirigibles are filled with hydrogen or helium.

Why does a balloon float in air? A balloon or a dirigible is lighter than air; that is, the total weight of the balloon or dirigible with its cargo is less than the total weight of the air which it displaces. It is forced upward by the greater pressure of the displaced air in the same way that a bubble of air is forced to the surface of water. The lifting force is the difference between the weight of the entire balloon and the weight of the displaced air. In order to provide a lifting force, the balloon bag must be filled with something which is less dense than air. The lifting force in a balloon filled with hot air is not great, because the difference between the density of the hot air and that of the colder air around the balloon is not great. Furthermore, as the hot air cools it contracts, and its density soon approaches that of the surrounding air. The lifting force of hydrogen is several times that of hot air. Hydrogen is much less dense, and therefore has a much greater lifting force, than helium. Unlike helium, however, hydrogen has the great disadvantage of being easily exploded with a spark.

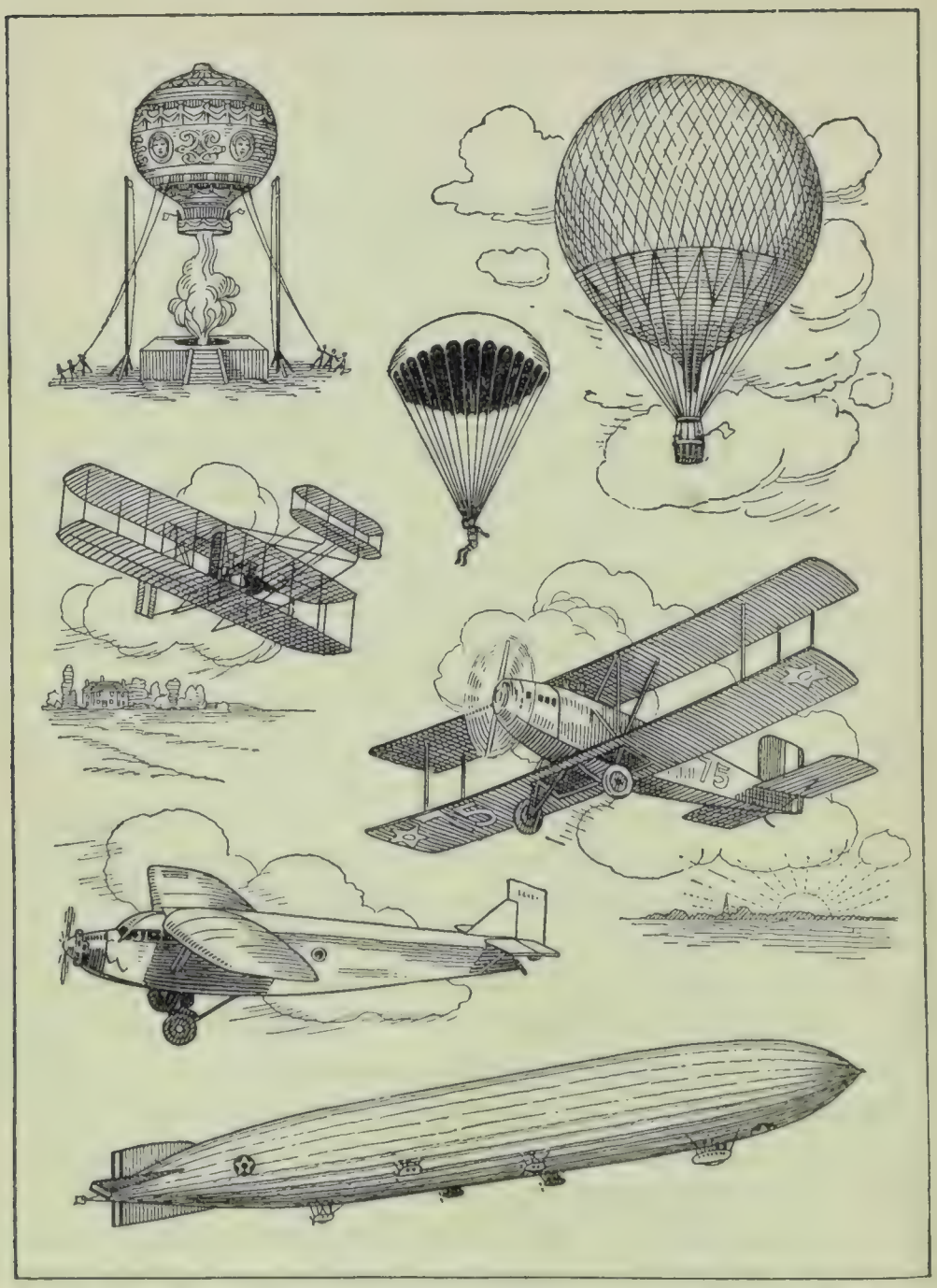


Fig. 354. From primitive to modern transportation in the air. The Montgolfier brothers' balloon; a modern balloon; a parachute; the first Wright airplane; a modern biplane; a modern monoplane; a dirigible balloon. How many other types of air transportation can you name?

Developing dirigibles from balloons. Balloons proved unsatisfactory for transportation, because they must go in whatever direction the wind blows them. But captive balloons (blimps), anchored to the ground by cables, were widely used for observation purposes during the World War. The first attempt to direct the course of a balloon was made about one hundred fifty years ago. An elongated balloon was rowed with silk-covered oars by hand and by this means was made to take a course slightly different from the direction of the wind. Encouraged by the slight success of this experiment, later inventors introduced first steam engines, then electric motors, and finally gas engines as the source of energy to drive balloons. Many other later experiments with balloons resulted in various important improvements and discoveries. The results of all these are found in the modern dirigible balloon.

Importance of dirigibles. The dirigible balloon has an aluminum framework containing many bags, each a separate balloon in itself. Equipped with powerful gas engines, such dirigibles have attained a speed of more than a mile a minute and have made journeys of thousands of miles carrying considerable weights in passengers and cargo. During the World War the Zeppelins (dirigible balloons named after their inventor, Count Zeppelin) crossed the English Channel from Germany and did some damage to portions of England. In 1926 Amundsen flew over the north pole in the dirigible *Norge*. Several dirigible journeys have more recently been made across the Atlantic Ocean, and in 1929 Count Eckener piloted the *Graf Zeppelin* around the world in twenty days. In the United States, however, several great dirigibles have met with disaster. The *Shenandoah* and *Akron* were each destroyed in a storm, and the *Macon* suddenly broke up during a cruise off the coast of California in 1935.

Airplanes. The first experiments with heavier-than-air machines were made with kites and with gliders, that is, planes that are without engines or other means of moving, but which glide or soar on the wind or air currents. A successful model airplane which flew forty yards was invented in 1848 by an Englishman named Stringfellow. In 1890 a Frenchman, Ader, invented a birdlike monoplane which was propelled by a screw propeller

driven by a 40 H.P. (horse-power) steam engine. In this machine he is said to have flown a distance of 150 feet. In 1903 the Wright brothers, greatly improving on earlier discoveries and inventions, produced the first really successful airplane. Since their historic flight at Kitty Hawk, North Carolina, the advances in aviation[1] have been many. Today hundreds of thousands of passengers travel annually a total of many millions of miles, and mail planes as well as passenger planes travel on regular schedules over both land and ocean.

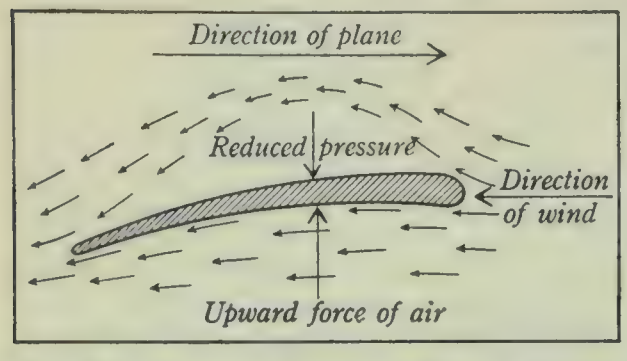


FIG. 355. Diagram showing why an airplane ascends. Why does the lifting force decrease as the plane ascends?

Why a kite flies. Most boys and girls have at some time flown a kite or perhaps made one. They know that the string must be attached to the kite in such a way that the kite slants forward against the wind when it is flying. They know also that a kite will not fly when there is no wind. They know, too, that if the wind is not very strong near the ground, they can start the kite by running with it, because by running they increase the wind which is blowing against the kite, thus forcing it up to a height where the wind is stronger.

It would be very easy to fly a kite on a calm day by pulling it after a moving automobile. Pulling the kite rapidly through the still air would be the same as if the kite were held still while a strong wind blew against it.

Why an airplane rises. The airplane makes the wind which blows against its planes or wings, causing it to rise and to remain in the air. The powerful gasoline engine turns the propeller, the blades of which are so shaped that the propeller acts as a screw. It bores through the air, pulling the plane after it, in much the same way as an auger or a gimlet bores its way through wood.

At first the airplane runs along the ground while it increases

[1] *Aviation* (a vi a'shun): the science of flying. *Aviator* (a'vi a tor): one who flies in a heavier-than-air machine.

its speed. The wings are so shaped as to increase the difference between the air pressure beneath and that directly above them. They are flat or slightly concave below and convex above (Fig. 355), and are tilted slightly upward so that the wind pushes against the under surface (Fig. 355) as against the under surface of the kite. At the same time also the wind is pushed upward and over the top of the wing. The result is that a partial vacuum or reduced air pressure is produced directly above the wing. Thus the lifting force secured from reducing the pressure on the upper surface of the wing may be twice as great as the direct lifting force due to the force of the moving wind against the under side. The faster the plane goes the greater is the difference in pressure against the top and the bottom of the wing, and hence the greater the lifting force. Also the greater the plane area the greater the lifting force.

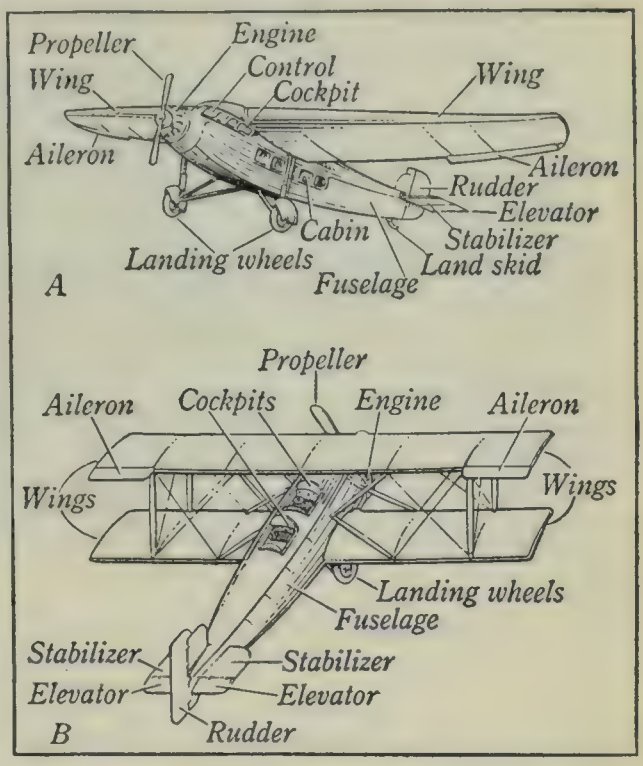


Fig. 356. Diagram showing the essential parts of a monoplane (*A*) and a biplane (*B*). Can you account for the fact that the monoplane is the swifter but the biplane is the stronger?

How an airplane is steered. The plane is steered from right to left by moving the rudder on the tail of the plane (Fig. 356). It is caused to ascend or descend by means of the elevators, which are small rudders or planes on the tail, the sides, or in front (Fig. 356). It is caused to bank or roll by means of the ailerons, or small extensions on the rear of the wings (Fig. 356).

Airplane speeds. To remain in the air an airplane must maintain a speed of at least sixty miles an hour. Speeds of over four hundred miles per hour have been attained. Colonel Charles A. Lindbergh made his flight from New York to Paris, 3610 miles,

Ewing Galloway

FIG. 357. An autogyro. **Special Report:** What are the advantages and disadvantages of an autogyro as compared with an airplane?

in $33\frac{1}{2}$ hours. Longer and more rapid flights have since been made, but none more striking than his famous achievement.

Types of airplanes. The most common types of airplanes are monoplanes, such as Colonel Lindbergh's *Spirit of St. Louis*, and biplanes, such as the great air liners. Planes having three or more pairs of wings are rarely built, because the increased weight and air resistance resulting from having more than two pairs is greater than the extra lifting force gained. The autogyro is an airplane which has on the top in addition to the wings a "windmill" which rotates horizontally (Fig. 357). This windmill enables the plane to remain stationary in the air or to rise or descend in much less space than is possible with an ordinary plane. The helicopter is somewhat like the autogyro, since it has large blades which rotate horizontally. Its blades, however, are driven by a gas engine. Recent experiments have been made with an autogyro without wings, with a plane having wings which move like a bird's, and with a plane having paddle wheels on each side. It is impossible to predict what strange types of airplanes may shortly be as common in the skies as the familiar types of monoplanes and biplanes now are.

Safety in air travel. Travel by airplane now has a high degree of safety. Yet it is impossible to prevent occasional serious accidents resulting in loss of life. All planes should be equipped with parachutes folded and strapped to the shoulders of passengers during the flight. In case of accident injuring the plane or forcing a landing in the mountains or in a forest, those in the plane could leap from it. The person falling counts ten slowly before he pulls on a ring attached to the parachute by a cord. The pull causes the parachute to open, permitting the person to float to the ground gently and in comparative safety.

Self-test on Problem XXVIII–C. (*Do not write in the book.*) **1.** As a balloon rises the difference between its total weight and that of the air it displaces becomes *greater*.

2. The balloon was *an earlier* form of airship than the dirigible.

3. Most of the lifting force on an airplane wing is due to the difference in air pressure on the *upper* surface of the wing and the partial vacuum on the *under* surface.

4. *Hydrogen* will carry a balloon higher than will *helium*.

5. The propellers of most airplanes *push* the airplanes through the air.

6. A safe descent can usually be made from an airplane by means of a _ _(?)_ _.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Can you give two reasons why it is easier to stand upon two feet than upon one?

2. Why is a book lying on its side more stable than when it is standing on its edge?

3. How many examples of stable bodies can you give? Can you explain why each is stable?

4. What advantage is derived from having a dirigible shaped somewhat like a fish?

5. Why is distilled water used in storage cells?

6. A heavier-than-air machine must begin to descend at once if the engine stalls. Why?

7. Can you name several ways in which the airplane is like a bird and several in which it is different?

Exercise on Scientific Method and Scientific Attitudes. Find in an encyclopedia or a history of science an account of the invention of the balloon by the Montgolfier brothers or of the airplane by the Wright brothers. Set down one after the other the stages or the steps in the progress toward a successful balloon or a successful flying machine; then, by referring to the phases of scientific method (p. 9), tell which phase each stage in your story illustrates. Also tell which of the scientific attitudes (pp. 12 and 13) are illustrated in your story.

Exercise on Scientific Attitudes. Which of the five comments following the incident reported here do you think a scientist would consider best? Can you support your choice by quoting one of the scientific attitudes?

A certain aviator always carried a four-leaf clover when he flew, to give him luck. One day he fell and was badly injured. He found that without knowing it until after his fall, he had somehow lost his four-leaf clover. He concluded that his fall was due to his having lost the clover leaf.

a. The conclusion is sound.
b. The conclusion is absurd.
c. The conclusion might be and probably is sound.
d. Four-leaf clovers certainly bring luck to some people.
e. The conclusion might be sound but isn't likely to be.

Special Reports. 1. Describe the construction and operation of the safety valve of a steam engine; of the governor.

2. Describe the construction and the operation of a steam turbine.

3. How many different uses of steam engines can you discover in one week in your town or neighborhood? How many of these have to do with transportation?

4. How many different uses of the gasoline engine can you discover in one week in your town or neighborhood? How many of these have to do with transportation?

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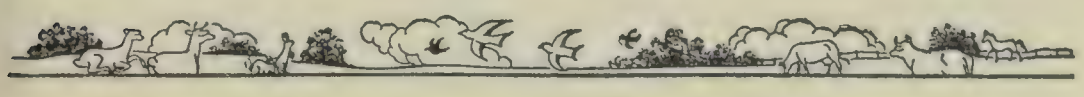
UNIT XII · *The Earth's Population*

PROBLEMS DISCUSSED IN THIS UNIT

When we hear someone speak of the earth's population, we usually think only of the people who live in all parts of the earth. But the people are only a very small part of the living population of the earth. There are millions of kinds of plants and animals, and there are enormous numbers of other plants and animals which formerly lived on the earth. Many kinds of plants and animals no longer exist. Also, not all of the different kinds of animals and plants now living are known to men.

Man is small when compared with the largest living things, such as the Sequoia trees and the sulfur-bottom whale. He is very large, however, when compared with the smallest insect you have ever seen. There are many things which live in water which are so small that the smallest insect seems large when compared with these very small living things. Yet all organisms, however large or small they may be, are alike in many ways, and all are different from nonliving things. In this unit we shall study the characteristics of living things. The major problems considered are these:

What are some important characteristics of living material?
What are the functions of living material?
How do green plants transform the sun's energy into food energy?
How are the forms and growth habits of green plants related to food-making?
How do non-green plants secure and use energy?
What are some important uses of plant materials?
How are certain animal activities related to man's welfare?
Of what importance are the conservation and care of wild life?
How do living things reproduce?
What are the principles which apply to reproduction and ways of living, and how can these be applied in improving living things?



Chapter XXIX · The Nature and Functions of Living Material

Questions this Chapter Answers

What are the characteristics of living cells?
What are the nature and the importance of protoplasm?
What are the nature and the cause of osmosis?
What is protoplasm, and what can it do?
What are the matter and the energy cycles?
How are the matter and the energy cycles related to the activities of protoplasm?
What are the nature and the importance of dormancy and hibernation?

Problem XXIX–A · What are Some Important Characteristics of Living Material?

Living cells. If you were to put into a jar of water some pond weeds and hay and were to set the jar aside in a warm place for several days, you would find that a foul-smelling scum would soon form on the top of the water. If then you were to examine a drop of this scum under a powerful microscope, you would see tiny animals, like those shown in Fig. 358, *A*, swimming rapidly in the water. If next you were to examine with the microscope a drop of sauerkraut juice, you would probably find some very small plants which looked like Fig. 358, *B*.

If then you were to examine with the microscope some of the thin skin from one of the layers of an onion and one of the smallest roots or root hairs of a newly sprouted mustard seed, you would find that they would look like Fig. 358, *C* and *D*.

*If you were to continue with the microscope your study of the bodies of plants and animals, you would find that every living thing is made up of one or more small boxlike units called cells (Fig. 358, *D*, *E*, and *F*). Thus, the small animals (Protozoa) in the liquid from the weeds and hay, and the tiny plants (bacteria) in the sauerkraut juice, are each made of only a single cell. Other

simple animals and plants have bodies made of only a few cells. A large plant such as a tree or a large animal such as a man is made of many millions of cells.

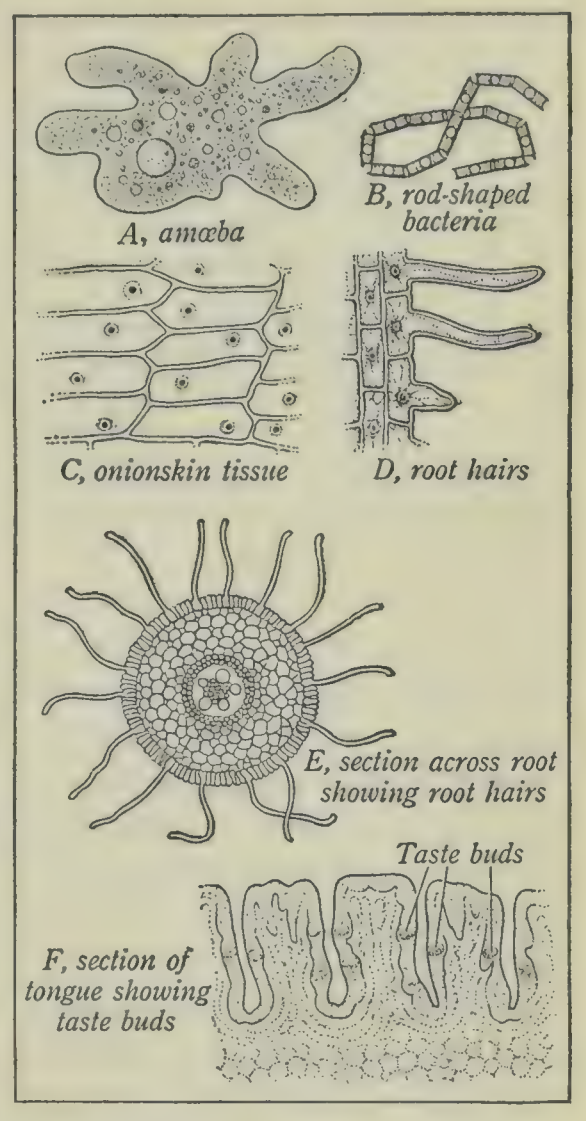


FIG. 358. Some common plant and animal cells (*A* and *B*), tissues (*C* and *D*), and organs (*E* and *F*). The cells composing the tongue are mostly too small to be indicated in *F*. **Special Report:** Robert Hooke's discovery of the cell

*__Characteristics of cells.__ In form and size cells vary greatly. Most of them are too small to be seen without the aid of a microscope. A group of similar cells having a similar purpose is called a tissue. Thus, the onionskin (Fig. 358, *C*) is a tissue. Exactly the same kinds of cells are never found in two different kinds of tissues. Moreover, within a tissue the cells vary in form because of their pressure against one another. The groups of tissue together form organs such as a hand, an eye, a leaf, and a flower (Fig. 358, *E* and *F*).

*It is believed that the one-celled organisms were the first living things on the earth. As ages passed, plants and animals came to have bodies of many cells.

*__Cell structure.__ The living material of every cell is called protoplasm. The protoplasm in any living thing, however, is never quite like the protoplasm in any other living thing. Also, the protoplasm in one tissue or organ of a plant or animal is never quite like that in any other tissue or organ of the same plant or animal. The protoplasm consists chiefly of two parts: (1) the more solid central part of the cell, the nucleus (Fig. 359), and

(2) the softer, thinner, and more liquid part, the cytoplasm. In some cells, for example, the root-hair cell (Fig. 358, *D*), the cytoplasm just within the cell wall is somewhat more dense, forming an inside wall. This cytoplasm wall is living. The outer cell wall is built up from the cytoplasm. Not all cells have heavy outer walls, but all have the essential parts—the cytoplasm and the nucleus.

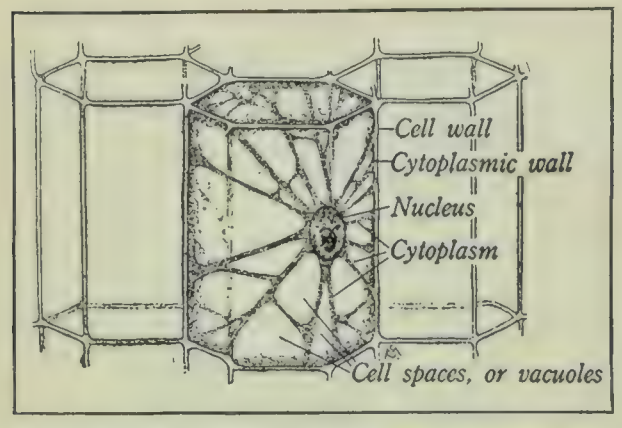


FIG. 359. A group of cells. What parts of the cell shown here are essential, and what parts are not?

***The importance of protoplasm.** The protoplasm of cells is the really living part of all living things. It is that part of plants and animals which does all that is done by them. No one knows just what it is that makes living protoplasm different from the material in dead cells, but we know that the difference is great. The functions of protoplasm which no other materials can perform show some of the important differences between things that are alive and those that are not. These functions will be discussed in the next problem.

Osmosis. Every living cell must be able to take in food and other materials which it needs and to get rid of waste products. An experiment will help to explain how these ends are accomplished.

Experiment 85. Will water pass through a living membrane[1]? The outer shell of a hen's egg is composed almost wholly of lime. Lime is readily dissolved by hydrochloric acid. Inside this lime shell is a tough membrane which we will compare with the wall of a cell such as that of a root hair (Fig. 358, *D*, p. 525). Dilute hydrochloric acid with water; then place an egg in a glass dish or beaker and cover it with the acid until the shell is dissolved. When the shell begins to get soft, pour the acid out and pour water into the dish. Keep an egg of the same size, not treated in any way, but to be used as

[1] *Membrane* (mem'brane): a thin tissue, usually consisting of only one or a few layers of cells, which forms a lining or covering.

a control. Leave in the dish of water the egg from which the lime shell has been removed (Fig. 360). Cover the dish in order to prevent evaporation. Observe whether the egg changes in size, and whether there is any change in the amount of water in the dish. In half an hour and at later periods compare the two eggs in size. What conclusions can you make from the results?

FIG. 360. **Exercise on Scientific Method (Using Controls):** How does the egg with its shell serve as a control in this experiment?

*What causes osmosis? When liquids such as the contents of the egg and water (Fig. 360) or sirup and water (Fig. 366, p. 537) are separated by a membrane, the liquids pass through the membrane in both directions. This fact may be explained thus: At first the molecules of water are more concentrated (that is, there are more molecules of water per cubic inch) outside than inside the egg. At the same time the molecules of egg material are more concentrated inside than outside the egg. All the molecules are constantly moving rapidly in all directions. Moreover, there is a tendency for each kind of molecule to go from the point of greatest concentration to points of lesser concentration. Hence some of them manage to pass through tiny holes or pores in the egg membrane. Egg molecules pass through the membrane with great difficulty. Hence the water molecules pass through the membrane into the egg in greater numbers than egg molecules pass outward through the membrane. A probable reason for this fact is that the water molecules are both swifter and smaller than the egg molecules. Finally the concentration of egg and of water molecules would become equal inside and outside the membrane. From then on, the number of egg molecules or of water molecules passing in both directions through the membrane would be the same. The process by which liquids and gases pass through moist membranes from a point where their molecules are more highly concentrated to a point where their molecules are less highly concentrated is known as osmosis. The pressure resulting from osmosis is called osmotic pressure. Osmosis is one type of diffusion (see Glossary).

Self-test on Problem XXIX–A. (*Do not write in the book.*) **1.** A dog, a tree, your hand, and your eye are *all* made of *large* living units called cells.

2. Every cell has a __(?)__ and __(?)__.

3. Select from the following list the objects which are not made of protoplasm: (1) a rabbit; (2) a rock; (3) one's ear; (4) a plant leaf; (5) an apple; (6) an elephant; (7) a walnut; (8) bone; (9) a shoe; (10) a board.

4. If liquids were unable to pass through moist membranes, there could be no (1) cells; (2) osmosis; (3) chlorophyll; (4) energy; (5) evaporation.

5. In osmosis the motion of molecules is from the point where the *liquid is* most *dense* to that where the *liquid is* less *dense.*

6. If an egg membrane partly filled with water were put into a *beaker* filled with a strong solution of salt water, the egg membrane would become more nearly *full.*

Problem XXIX–B · What are the Functions of Protoplasm?

New protoplasm. Every living thing must secure energy in the form of food. The food materials, however, are of no use to the plant or animal until they have been changed into the proper liquid form for use by protoplasm. This process of change is called digestion. Then the digested food must be taken into and made a part of the living protoplasm. This process is called assimilation. Exactly what happens during assimilation is not known. It is known, however, that assimilation results (1) in growth, that is, in making more protoplasm, and (2) in replacing protoplasm that has been worn out through use, or in both. Thus, in assimilating digested food, protoplasm makes material that was not living into living material.

Oxidation. We have already learned that when fuel is burned in a stove or an engine, the oxidation of the fuel releases heat energy, while carbon dioxide and water are given off as waste products. Let us see whether oxidation in living things produces similar results.

Experiment 86. Do the amounts of oxygen and carbon dioxide increase or decrease where green plants are growing? Arrange the apparatus as shown in Fig. 361 and leave it overnight. Place another beaker of

limewater outside the bell jar, to serve as a control. Does the limewater in either dish have a coating of lime deposit? Light a splinter and place it within the bell jar to see if there is oxygen enough to permit the splinter to burn. Fill in the blanks in the following sentence: This experiment shows that green plants _ _(?)_ _ carbon dioxide and _ _(?)_ _ oxygen. Does this experiment indicate that oxidation does or does not take place in plants? Explain.

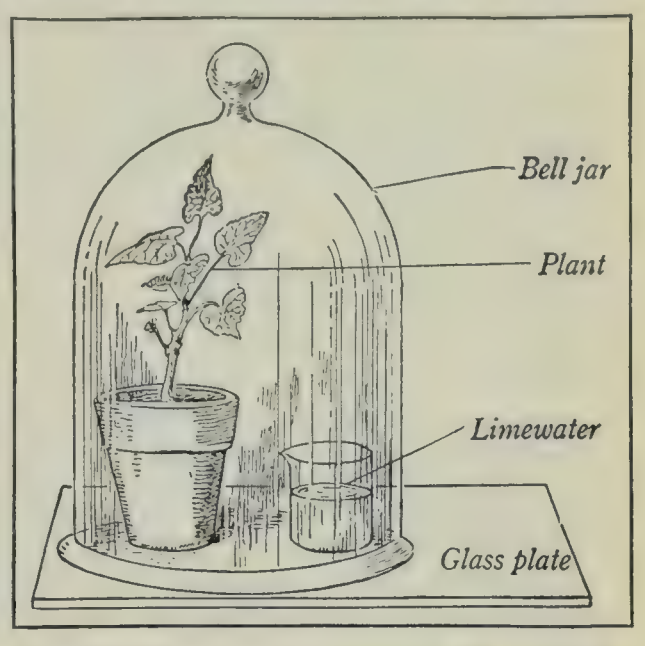


FIG. 361. **Exercise on Scientific Method (Inventing Experiments)**: Can you suggest anything which might be used here in place of the bell jar?

Experiment 87. Do animals give off heat, carbon dioxide, and water? Cover the bottom of a battery jar with straw or excelsior for a "nest"; then put into the jar a rabbit, a guinea pig, or a white rat. Partly cover the jar with a glass plate, leaving room for air to enter. After a few hours compare the temperature inside and outside the jar with a thermometer. Dip a glass rod into clear limewater; then thrust the rod into the jar. Observe the limewater. Repeat, holding the rod covered with limewater outside the jar. Observe the limewater and compare its condition with that of the limewater in the preceding step. Cool a glass plate or tumbler as much as you can without having dew form on it when it is in the room. Put the tumbler into the jar to see whether dew forms. Does it? Answer with a complete statement the question at the beginning of this experiment and justify your statement.

Exercise on scientific method (criticizing experiments). Did Experiment 86 furnish enough evidence to justify an answer to the question at the beginning of the experiment? Explain. How did the second dish of limewater serve as a control? Were any other controls needed? Explain. Did Experiment 87 furnish enough evidence to justify an answer to the question at the beginning of the experiment? Explain. Were there a sufficient number of controls in this experiment? Explain.

Experiment 88. What effect does the gas given off by germinating pea or bean seeds have on limewater? Do germinating seeds give off heat? Fill a bottle about one-third full of pea or bean seeds. Pour water over them and then drain off the water, leaving the seeds moist with but a little water in the bottom of the bottle. Put a plug of cotton in the bottle and leave it for one or two days in a warm place. Note on the thermometer the temperature of the air outside the bottle; then insert the rubber stopper, in which the glass tube and the thermometer have been placed. With the other end of the tube in the limewater, press the rubber stopper tightly enough to force air from the bean bottle into the limewater (Fig. 362). What change do you now observe in the limewater? Does oxidation take place in germinating seeds? Explain. After a few minutes observe the temperature of the air in the bottle. Is the temperature above the germinating seeds higher or lower than that of the outside air? Answer with a complete statement each question asked in this experiment. Give a reason for each answer.

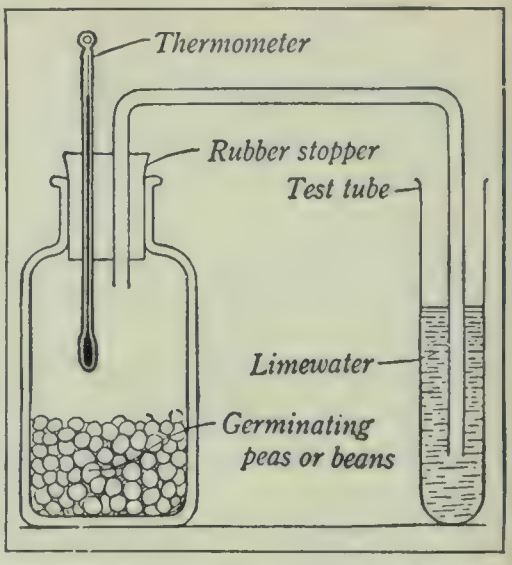


FIG. 362. Exercise on Scientific Method (Inventing Experiments): What experiments would need to be performed before we could answer the question "Do all germinating seeds give off heat and carbon dioxide?"

The energy and matter cycles. Protoplasm is a complex substance. Consequently much energy is used in building protoplasm from the simpler compounds which make up digested foods. When protoplasm is consumed, the energy stored in it is set free. Thus the energy in the plant or animal body may be changed to heat, light, or other forms of energy when the body decays or burns; or when it is eaten its energy may be changed to heat or to chemical energy and stored in the body of another plant or animal. Energy, therefore, is used over and over again in an endless round. This continuous change of energy from age to age is called the energy cycle. Fig. 85, p. 133, furnishes an example of the energy cycle.

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FIG. 363. Canadian geese in the Philadelphia zoo. **Self-test on Scientific Principles:** How does this picture illustrate the principle "The matter and energy cycles make continued life possible"?

When protoplasm decays, it not only releases the energy it contained but also breaks down into simpler substances. These include the simple compounds, water and carbon dioxide, and compounds of nitrogen, sulfur, potassium, and other elements. These products of broken-down protoplasm may later be used again in building new organisms. Thus the same food elements may have been used by living things over and over, many hundreds of times. The carbon, sulfur, nitrogen, or iron now in a plant or animal body may have been parts of hundreds of other plants or animals. This continuous use of the same materials by animals and plants from century to century is known as the matter cycle (see Fig. 85, p. 133).

*Relation of the matter and energy cycles to the activities of protoplasm. It will be seen that building-up processes and tearing-down processes are constantly going on at the same time. If this were not the case, there would soon be no life. If there were no building up of protoplasm, all living things would at once cease

to grow or to replace injured or worn-out parts, and there could be no new organisms. If there were no breaking down, or decay, of protoplasm, soon all the available[1] energy and building materials would be stored in the bodies of living things. Growth and production of new organisms would soon become impossible (Fig. 363). Animals would soon find great difficulty in moving about, because the earth's surface would be so completely covered with the dead forms of plants and animals. Thus the matter and energy cycles make continued life possible.

Growth. As the result of its assimilation of food, the cell enlarges or grows. It finally becomes full-grown, or mature, just as does an animal or plant. When a cell has become mature, it may divide into two cells, and each of these in turn into two others, and so on. Such division results in more cells.

Consequently a plant or an animal grows as the number of cells composing its body increases. Growth of an organism may be rapid or slow. Plants usually grow most rapidly in certain kinds of weather or in certain seasons. For example, a plant of Indian corn may grow several inches in length in a single day and night, and a squash plant has been known to grow over two feet in length in twenty-four hours. A young pig or a young dog may in a few months increase its weight to many times what it was at birth. Assimilation in young animals and plants results chiefly in growth, that is, the production of new cells. Assimilation in a full-grown organism results chiefly in replacement of worn-out protoplasm.

New organisms from old ones. When cells grow and divide to form new cells, there is an increase in the number of cells and in the size of the whole organism. The entire mass of cells, however, still forms but one plant or animal. New individuals are formed only when some part of this plant or animal is separated from it and continues to live and grow separately. Thus we could cut off a branch of a common begonia plant or a willow tree and, by planting it properly, could produce a new begonia or a new willow plant. The protoplasm of the cells is able to keep growing and to produce new roots, stem, and leaves. The production of new living things is called reproduction (Fig. 364).

[1] *Available* (a vail'a bl): ready at hand for use; able to be used

Food-making. The protoplasm of green plants is able to transform the sun's energy into food. This process of food-making indirectly furnishes all the food energy in the world. Food-making will be discussed more fully later.

Newton H. Hartman

FIG. 364. **Self-test on Scientific Principles:** What evidence here supports the principle that higher animals protect and care for their young while the latter are in the period of infancy?

Working and resting. Living things do not work all the time. Protoplasm, the living cells, the whole plant or animal body, may work for a shorter or longer period, but they also rest for shorter or longer periods. If, however, all activity[1] of protoplasm should ever stop, life itself would be stopped. Usually the night is a period of relative inactivity of protoplasm compared with the day. Green plants and many kinds of animals do most of their resting at night. During the night the green plants are not making food. The plant's protoplasm may, however, assimilate more food during the night than during the day. In some kinds of plants, moreover, it is known that increase in the length of the twigs and leaves takes place more at night than by day.

***Dormancy** (see Glossary). Many of our familiar plants are dormant during winter or during a long dry period. In the autumn the leaves may drop from trees and shrubs, and for half a year or more the whole plant may seem as if it were dead. When spring returns, however, the inactive protoplasm begins work. As the year advances, new leaves are produced, new growth is made.

[1] *Activity* (ak tiv'i ty): state of being active.

U. S. Biological Survey

FIG. 365. Two animals that hibernate: *A*, an opossum (it is not dead but is merely "playing possum"); *B*, a bat, a valuable insect-eating animal (this one, a pet, is eating an insect larva). Self-test on Scientific Attitudes: There is a foolish old belief that bats are dangerous animals which try to crawl into one's hair. Which scientific attitudes (pp. 12 and 13) relate to this superstition?

Flowers and seeds are produced, and food energy is stored. The plant then accommodates, or adjusts, itself again to another coming period of cold or dryness and another period of rest and dormancy.

Plants may become more or less dormant during any long period of cold or dry weather. The fact that the plant is doing little or nothing during any unfavorable period means that at these times the protoplasm transforms little energy. Moreover, during these periods much and sometimes all the food used by the protoplasm comes from the plant's stored supply. Plant roots, stems, and seeds may remain dormant for several years and then grow when favorable conditions are provided. The seeds of some plants may be kept for many years, with the new plants within still living and ready to grow if they are given favorable moisture and temperature.

*Hibernation. Animals, like plants, have periods of activity and dormancy (Fig. 365). During the long winter periods of some regions many kinds of animals cease their common work of getting food, caring for their young, playing with their kind, or fighting their enemies. This dormancy is called hibernation. Snakes and lizards and many other animals go into holes where freezing temperatures either do not occur or else occur very slowly. Frogs

(at least some kinds) dig deeply into the mud at the bottom of ponds and lakes and either do not freeze or else freeze and thaw slowly. Ants and many other insects dig into wood or the earth and pass the winter in a dormant condition, sometimes frozen. Woodchucks (Fig. 171, p. 244) go down into their burrows, and bears go into hollow logs or stumps or into caves and remain dormant until spring approaches. Bats hang by their claws in caves or hollow trees. During the coldest winter weather some kinds of squirrels remain for considerable periods in the ball-shaped nests which they have previously made of leaves in the branches of trees; other kinds hibernate in burrows underground.

*In the dormant condition protoplasm can live through such extremes of heat and cold as could not possibly be endured if these extremes should suddenly come during the active growing season. Seeds can be frozen slowly, or may be heated slowly to the temperature of boiling water, and still grow if they are quite dry and if all changes in temperature are made slowly. Many of the simpler animals and even such complex animals as frogs and snakes can become frozen without apparent injury.

***Summary of characteristics of protoplasm.** Protoplasm is living substance. Its essential parts are the cytoplasm and the nucleus. The outer part of the cytoplasm produces the cell wall. The cell includes the wall, the cytoplasm, the nucleus, any included water or cell sap, air spaces, and any unused food or other substances that may be contained.

*Protoplasm has the ability to digest and assimilate food material. Protoplasm cannot exist without water and the energy of heat and food. Protoplasm oxidizes food, changing part of it into heat energy and giving off carbon dioxide and water as waste products. It can replace any part of itself that may have become worn-out, and it can produce new protoplasm. Protoplasm can produce new cells, and by so doing it causes growth. Protoplasm can produce cells with which to reproduce plants and animals. Protoplasm and the bodies built by it have periods of action and periods of rest. Protoplasm stores and releases the energy by means of which all animal and plant work is done. The characteristics of protoplasm make up the chief differences between living and nonliving matter.

Self-test on Problem XXIX–B. (*Do not write in the book.*) **1.** The only substance which can make living material out of nonliving material is __(?)__.

2. A mosquito bites a man; the mosquito is eaten by a fish; the fish is eaten by the man. This series of events furnishes an example both of the __(?)__ cycle and the __(?)__ cycle.

3. When living things use food, __(?)__ and __(?)__ are always given off as waste products.

4. Animals and plants grow chiefly by increase in the *size* of their cells.

5. When a living thing *grows*, a portion of it separates and continues life independently.

6. During a period of dormancy, or hibernation, a plant or an animal uses much *less energy* than during other periods.

7. *Few* kinds of protoplasm can exist long without water.

Self-test on Scientific Principles. 1. Can you give an original example illustrating the matter cycle? the energy cycle?

2. Can you explain this principle: "If there were no death or decay, a time would soon come when no new animals or plants could be produced"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. For what purposes are new cells being formed in the bodies of animals and plants which already have their full growth?

2. In general, are new cells formed more abundantly in young or in old organisms? Explain.

3. Houdini, a celebrated "magician," once allowed himself to be sealed in an airtight coffin which was lowered to the bottom of a tank of water. After 45 minutes the coffin was raised and opened and Houdini emerged from it unharmed. Can you explain why he did not smother?

Projects. 1. To find out how much water will pass by osmosis through a membrane. Arrange the apparatus as in Fig. 366. Note how much water passes through the membrane in two hours; in a day. Test the water outside the membrane for sugar. (See Experiment 110, p. 639.)

2. To find out how high water will be forced upward in a tube by osmosis. Arrange the apparatus as in Fig. 366 except that a long glass tube is joined by a piece of rubber tubing to the straight stem of a thistle tube. Measure the height of the water column from time to time.

3. To study osmosis in a carrot, a potato, or a turnip. Carefully hollow out a carrot, a potato, or a turnip. Be careful to make in the vegetable a hole the diameter of a one-hole rubber stopper. Fill the hole

in the vegetable with sirup. Insert a long glass tube in the rubber stopper. Put a rubber band around the vegetable to strengthen its walls, then insert the rubber stopper snugly in the hole in the vegetable. Seal the spaces around the stopper with hot paraffin. Support the tube with a support stand.

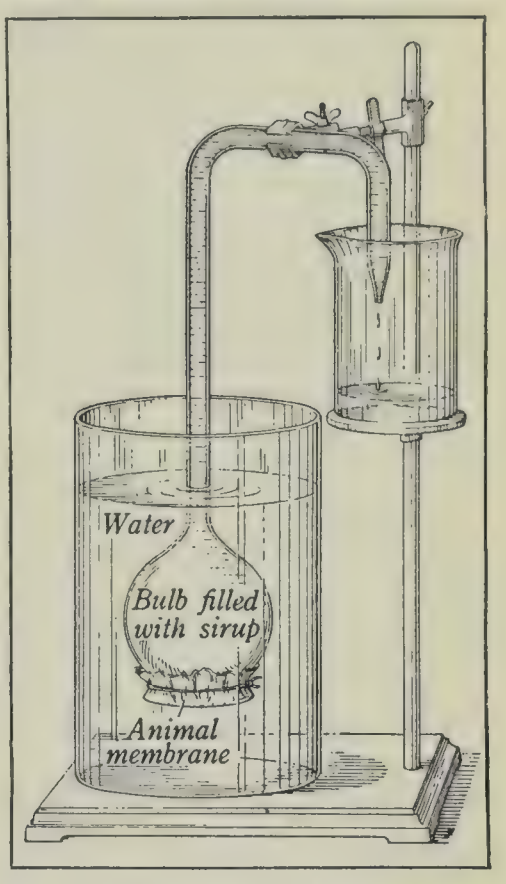

FIG. 366. Diagram of apparatus for studying osmosis. Should you expect the flow of water into the bulb to be more or less rapid at the start than later? Explain

Exercise on Scientific Attitudes. Before the Civil War a foreigner visited this country. He landed at Savannah, Georgia, where he saw many more Negroes than white people. He returned to his own country and reported that there were considerably fewer whites than Negroes in North America. Which of these five statements would a scientist consider to be the best comment on the foreigner's report concerning the population of North America? Defend your choice by selecting one of the scientific attitudes on pages 12 and 13?

a. The foreigner's report was founded on fact.

b. His report was founded on facts true only of a limited area of North America.

c. His report was founded on scientific observation.

d. His report was founded on unscientific observation instead of fact.

e. His report was not founded on fact.

Special Reports. 1. One-celled animals.

2. One-celled plants.

3. Make a list of animals of your region which spend part or all of the winter hibernating.

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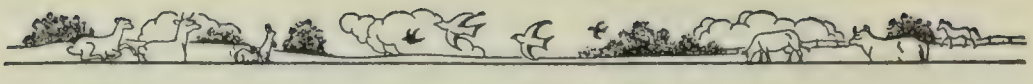


Chapter XXX · Structures, Habits, and Uses of Plants

Questions this Chapter Answers

Why are green plants important?
What are the principal plant structures, and what are their functions?
Where and how does photosynthesis take place?
What is the oxygen and carbon-dioxide cycle?
In what ways may the process of photosynthesis be compared with a mechanical manufacturing process?
What are the nature and the importance of transpiration?
What are the great groups of plants?
How is the form of a green plant suited to the work of photosynthesis?
Where do green plants store surplus food?
What are the characteristics and growth activities of such dependent plants as molds, yeasts, bacteria, mushrooms, and other fungi?
What are the structures and life habits of parasites and saprophytes?
What are some important uses of plant materials?

Problem XXX–A · How do Green Plants Transform the Sun's Energy into Food Energy?

Green plants and the world's food supply. You have seen accounts in the newspapers of famine in distant lands which was caused by the failure of the food crops. Whenever drought, dust storms, floods, insect pests, or other unusual circumstances cause the crops to fail in any large area, the whole country suffers directly or indirectly. The crop plants are the foundation of the country's prosperity. We can realize the truth of the statement that the work of green plants is the foundation of the world's food supply, not only that of human beings but also that of every other kind of living thing. Let us study a typical green plant in order to learn how its various organs and structures are related to food-making.

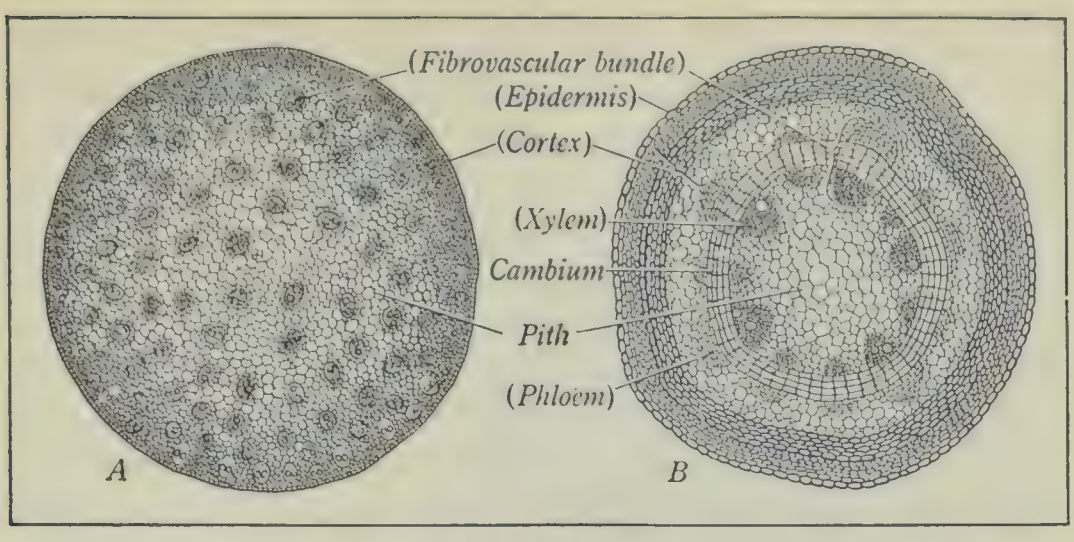


FIG. 367. Stem structures. With the aid of the text, can you explain the function of each of these structures?

Experiment 89. What are the characteristics of a typical green plant? Grow some young bean or pea seedlings. Carefully remove several of them with all the soil around their roots. Carefully wash all soil from the roots. Describe in detail, or sketch, the entire plant. If a compound microscope is at hand, make microscope slides of root hairs, and of cross sections of a small root, of the stem, and of a leaf. Sketch or describe in detail the structures which you observe.

Functions of the roots. The important divisions of a green plant are its roots, stem, and branches, its leaves, and its flowers and seeds. We are familiar with the fact that the roots serve to anchor the plant in the earth. But they also help indirectly in the food-making process. The small root hairs on the smallest roots (Fig. 358, *D* and *E*, p. 525) are the structures by which the plant secures the soil water. These root hairs are single cells. The soil water and the dissolved compounds of nitrogen, iron, sulfur, and many other chemical elements which it contains are needed by the plant in food-making. The soil water passes through the walls of the root hairs by osmosis. The water then passes from the root hairs first into surface cells of the root and then to tubes in the middle of the root. From these it passes to the larger and larger roots, then to the stem, and finally to the leaves, where most of the food is manufactured. Not all the water is used in

the food-making process. Enough remains in all parts of the plant to keep them moist and to keep the cells and tissues filled (turgid). The water in plants in which plant substances and food and also materials from the soil are dissolved is called sap.

U. S. Forest Service

FIG. 368. The diary of a pine tree. In the earlier years of this tree's life it was crowded by other trees and its supply of light was not nearly enough. During these years the growth rings were so close together that they cannot be made out in the picture. Then all the larger timber was cut away, allowing abundant light for this tree. How many years did the tree live under favorable lighting?

Structures of the stems. Just inside the bark of tree stems are the vascular[1] bundles (Fig. 367). These consist of three kinds of cells. The outside layer (phloem) consists of the cells through which sap containing food travels downward through the stem. The next layer is the growing part of the stem (cambium). The inner layer (xylem) consists of the woody cells through which the soil water rises through the stem. The vascular bundles are not found in the stems only. They are continuous from the roots through the stems and leaves. The vascular bundles of the leaves are called veins. Thus they provide a transportation system for water and manufactured food throughout the entire plant.

Each growing season the growing layer (cambium) produces a new layer of woody[2] tissue in the stem, and a new layer of bark beneath the old bark. In this way the stem and branches are getting thicker each year by means of the yearly, or annual, growth rings of wood. By counting the growth rings of a tree one can

[1] *Vascular* (vas'ku lar): having to do with the circulation of sap in plants and of blood in animals.

[2] *Woody:* of the nature of wood; like wood.

learn its age fairly accurately (Fig. 368). The stem of a tree consists largely of the heavy cell walls of old wood cells in which the protoplasm is no longer living. These old cell walls are useful for support to the plant even though they are not alive. Indeed, a hollow tree whose central wood has decayed will still live and work if it is strong enough to support its load.

Functions of the stems. Stems and branches render important help in food-making: (1) they hold the leaves up in the air, where they can do their work; (2) they carry water and other food material to the leaves and carry manufactured foods down to other parts of the stem and to the roots; (3) in some plants they actually take part in the food-making.

Functions of leaves. The chief functions of the leaves of green plants are (1) to manufacture food (the process of photosynthesis), (2) to get rid of excess water (the process of transpiration), and (3) to take in air and give off waste gases (the process of respiration). The processes of transpiration and respiration assist indirectly in the process of photosynthesis, as will be explained.

***The food-making substance.** Green plants are green because the cells of the leaves and often those of the twigs and smaller stems contain a coloring substance called chlorophyll. Chlorophyll is the substance that is most important in manufacturing food. The raw materials needed by the chlorophyll are (1) the carbon dioxide from the air and (2) water and dissolved substances from the soil.

How do the raw materials reach the cells? The surface of a leaf has special openings or pores (stomata) through which carbon dioxide can go into the leaf (Fig. 369). The carbon dioxide is dissolved by water. It therefore passes by osmosis through the moist walls into the leaf cells. The soil water with its dissolved substances passes into the leaf through the vascular bundles, or veins. It passes from the veins by osmosis to all the cells in the leaf.

The food-making process. Water and carbon dioxide are not food for a plant. Green plants would starve and die if they could not change these materials into new compounds which they can use as food. Energy is needed to enable chlorophyll to do its part of the work of food-making. An experiment will show what is the source of this energy.

Experiment 90. What happens when iodine is added to a substance containing starch? Put into each of two test tubes a little cornstarch; into another a little sugar; into a fourth a little lard or cooking oil; and into the fifth a little lean meat or white of egg. Only the first two of the test tubes contain any starch whatever. Add to each test tube a little water. Boil the contents of each test tube for a few minutes; then to each add a few drops of a solution of iodine crystals in alcohol or in water. What do you observe in each test tube? Answer with a complete sentence the question asked at the beginning of this experiment. This color change when iodine is added to a solution containing starch is known as the starch test.

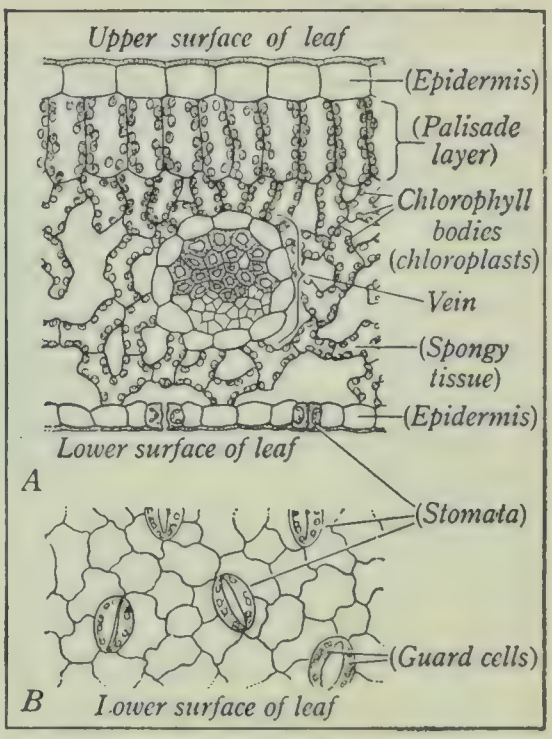


FIG. 369. *A*, cross section of a leaf, magnified; *B*, leaf surface, magnified to show stomata. **Experiment 91:** What effect does alcohol have on green leaves? Heat water to the boiling point in a beaker. Remove the leaves. Fill a test tube nearly full of alcohol. Place several green leaves in the test tube. Place the test tube in the beaker of hot water and allow the leaves to boil for a few minutes in the alcohol. Remove the leaves. Answer with a complete sentence the question asked at the beginning of this experiment

Experiment 92. Is the energy of sunshine necessary in order that the leaves of a green plant may make starch? By the use of pins fasten disks of black paper or corks on several leaves of a geranium or nasturtium plant, so that a part of each leaf is covered from the sunlight. Then allow the plant to be in sunlight for a few hours. Remove the chlorophyll from several of the leaves by boiling them in alcohol as in Experiment 91. Then dip a leaf in a weak solution of iodine dissolved in alcohol and examine to see any differences in the color produced by the iodine. Does any part of the leaf which has been dipped in the iodine solution have the same color as the cornstarch when iodine was added in Experiment 90? Answer with a complete statement the question asked at the beginning of this experiment.

Exercise on scientific method (isolating the experimental factor and using controls). The experimental factor in Experiment 90 was starch. Explain. The experimental factor in Experiment 92 was sunlight. Explain. What were the controls in Experiment 90? How did the portions of the leaves which were not covered serve as controls in Experiment 92?

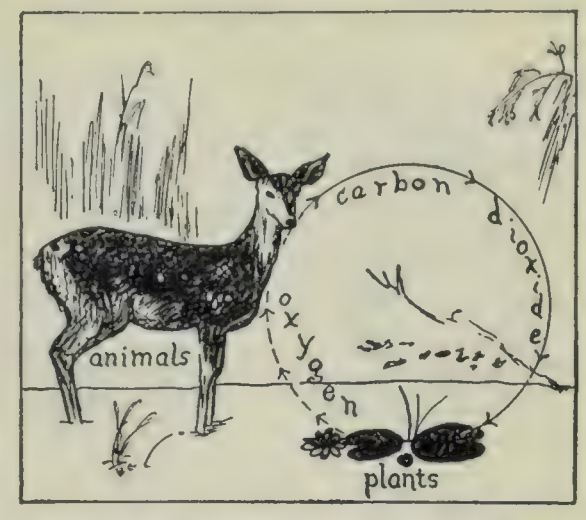


FIG. 370. This drawing to illustrate the oxygen-carbon-dioxide cycle was made by a high-school pupil in a general-science class. Can you explain it?

What is photosynthesis? When sunlight falls upon the green plant, the chlorophyll absorbs energy from the sunlight. By means of this energy it changes the carbon dioxide and water into sugars and starches. The process by which chlorophyll makes sugar and starch from carbon dioxide and water, using the energy from the sun, is called photosynthesis. Sugars and starches are carbohydrate foods (see Glossary). Part of the carbohydrate foods are later changed by the plants into fats and proteins. Fats, like starches and sugars, are composed only of oxygen, hydrogen, and carbon. Proteins consist of these three elements combined also with nitrogen, sulfur, iron, potassium, and many other elements.

***The oxygen-carbon-dioxide cycle.** Not all the oxygen from the carbon dioxide and the water is used by the chlorophyll in making carbohydrates. Some of it is set free and added to the air's supply of oxygen. Oxygen is breathed by animals and is used by them in oxidizing or burning their food. Carbon dioxide is formed in this process. Thus green plants in storing energy in the form of food use carbon dioxide and give off oxygen. Animals in getting the energy from food use oxygen and give off carbon dioxide. This continual series of chemical changes is called the oxygen-carbon-dioxide cycle (Fig. 370). When green plants are not doing chlorophyll work, they use some oxygen and give off carbon dioxide.

A perfect balance of the oxygen-carbon-dioxide cycle is sometimes secured in an aquarium in which fish, possibly other animals, and plants are living together. In such aquaria the animals release carbon dioxide which the plants need in their food-making. The plants use carbon dioxide and release oxygen which the animals need. If the animals eat too much of the plants, sooner or later the plants will disappear. If the animals cannot get food enough, they will die. In most aquaria, however, it is necessary to give constant care to see that proper food and conditions are provided for each of the organisms in them.

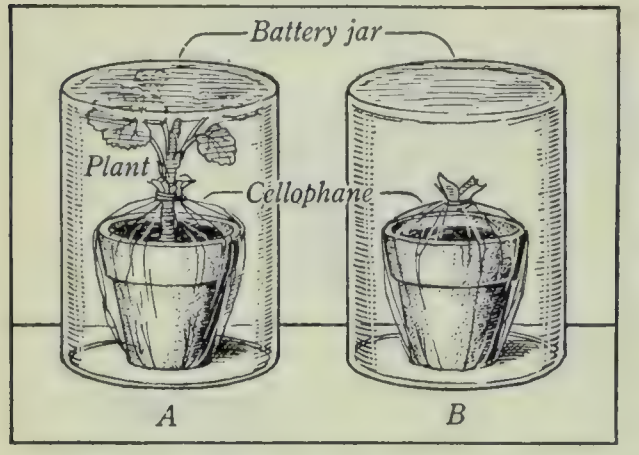


FIG. 371. Exercise on Scientific Method (Using Controls and Check Experiments): What are the control and the check experiments in Experiment 93?

*Summary of photosynthesis. The process of photosynthesis may be compared with a manufacturing process, thus:

Source of energy	The sun
Raw materials	Soil water and carbon dioxide from the air
Manufacturing plant	The leaves and the bark of young stems
The machines	Chlorophyll
The transportation system within the factory	The vascular bundles
The product	Carbohydrates, chiefly starch and sugar
The by-product	Oxygen

Transpiration. *Experiment 93.* Does water evaporate from the leaves of a plant? Place a well-watered potted plant in a cellophane bag tied snugly around the stem (Fig. 371). In the same way tie cellophane completely over an exactly similar pot filled, like the other, with moist soil. This pot is the control. Invert a battery jar or a bell jar over each pot (Fig. 371). After an hour or so examine the inside surfaces of both jars. What do you observe? Now as a check experiment strip the leaves from the plant and cover its pot with cellophane exactly as at first. Place over it a dry bell jar.

After an hour or so observe the inside surfaces of the bell jar. Answer with a complete sentence the question at the beginning of this experiment.

Since water is constantly passing from the ground into a plant through its roots, water must also be constantly escaping from the plant. The water not needed by the plant evaporates from the cell walls of each leaf into the open spaces within the leaf. It then escapes along with the oxygen released during photosynthesis. It passes out through the same pores through which the carbon dioxide used in photosynthesis enters. The evaporation of water from plant leaves is known as transpiration (see Fig. 20, p. 36). The amount of transpiration varies in different seasons and in different kinds of weather. Also, more transpiration takes place during the daylight hours than at night.

*Transpiration is constantly removing water from the upper parts of plants. It therefore helps to keep the water moving upward. The osmotic pressure from millions of root hairs also helps to force the water upward through the plant. A third process, capillarity (see Glossary), likewise helps. The plant stem consists of many small tubes. An experiment will show the nature of capillarity in plant stems.

Experiment 94. Does water rise higher in small tubes or in large tubes? Secure some glass tubes with extremely small openings. Such tubes are called capillary (meaning "hairlike") tubes. Place the tubes upright, the lower ends in a beaker of colored water. Answer the question asked at the beginning of this experiment.

***Kinds of plants.** In our discussion of the food-making of green plants we have thus far described, and in the following problem shall describe, chiefly the characteristics and activities of the more complex plants. There are, however, four great groups of plants. The lowest includes the one-celled plants such as bacteria, yeasts and molds, algae (see Glossary), and other many-celled but very simple plants. The second group is represented by the mosses. The third is represented by the ferns. The fourth and highest group includes all the flowering plants. To this group belong the forest trees and the fruits and grains and most of the other plants which are important sources of man's food and tim-

ber. Plants with chlorophyll are numerous in all four groups. Plants without chlorophyll are found chiefly in the lowest group.

*Plants are found in every part of the earth, on the land, in the oceans, and even high in the air. They are most abundant in tropical regions, but a few kinds of mosses and simpler plants are found in polar regions, and flowering plants on the Arctic islands.

Self-test on Problem XXX–A . (*Do not write in the book.*) **1.** Water enters a plant through its (1) leaves; (2) flowers; (3) stem; (4) root hairs; (5) bark.

2. Water enters the plant by the process of *photosynthesis.*

3. Arrange the following plant structures in their proper order, beginning with the outside of the tree trunk; (1) the layer through which sap travels upward; (2) outer bark; (3) the growing layer; (4) the layer through which sap travels downward; (5) dead wood cells.

4. Sap is carried upward and downward through the __(?)__ bundles.

5. Most of the work of photosynthesis is carried on by the green material called __(?)__ which is found chiefly in the *stems* of plants.

6. The source of energy used in the process of photosynthesis is the __(?)__.

7. Water vapor and oxygen leave the plant, and carbon dioxide enters, chiefly through small pores in the *stems* of plants.

8. Discuss photosynthesis (see "To the Student," p. xv).

9. Arrange these groups of plants in proper order from lowest to highest: (1) flowering plants; (2) single-celled plants; (3) ferns; (4) mosses.

10. The foods which green plants make by the process of photosynthesis are *proteins* and *sugars.*

Problem XXX–B · How are the Forms and Growth Habits of Green Plants Related to Photosynthesis?

Leaf and stem habits. *Experiment 95.* How are leaves arranged on stems to secure good lighting? Examine such plants as sunflowers, beans, squashes or pumpkins, dandelions, lilacs, and potted house plants, and write a description of the arrangement of leaves on stems to secure good lighting. Are all the leaves equally well lighted? Are any in shade throughout the whole day? Is there evidence that the leaves have grown into positions that will give all of them good light?

Experiment 96. Will the stems of house plants grow toward or away from the light? Place in the window several potted plants such as geranium or coleus. Observe their stems. After several days again observe their stems. Have they continued to grow in the same directions as before they were put in the window? Turn all the plants halfway round. Again after a few days observe the stems. Answer with a complete sentence the question at the beginning of this experiment.

Brooklyn Botanic Garden

FIG. 372. From what direction do you think the light came to this plant?

Exercise on scientific method (using controls and check experiments). What were the controls in this experiment? Why did turning the plants serve as a check experiment?

Kinds and arrangement of leaves. There are very many kinds of leaves, there are many ways in which they are arranged on the stems and branches, and there is a good deal of variation in the form of leaves on the same plant. The leaves of a plant may be large and few, as on corn, sunflowers, and beans; or they may be many and small, as on rosebushes, hedges, and spruce trees. The leaves may be undivided, as in peach and elm trees; or they may be divided, as in white or red oaks, carrots, and cress. They may consist of many small leaves on one leafstalk,— that is, the leaves may be compound,— as in clover, roses, and horse-chestnut or walnut trees. There are almost endless variations in the forms of leaves. Occasionally one may even find several leaf forms on the same plant, as on the sassafras tree. But whatever the form or arrangement of leaves on a plant may be, it will be found to be suited to the chief activity of the leaves, namely food-making (Fig. 372).

Stems and photosynthesis. Plant stems grow in such ways that their leaves are effectively presented to the sunlight. Some stems are not strong enough to hold up their own weight and

also that of their leaves. Examples are those of the pumpkin and watermelon, the trumpet creeper, the morning-glory, the woodbine, peas, beans, and grapes. The stems of these plants have the habit of running along on the ground or climbing on fences, on houses, or on stouter plants (Fig. 373).

FIG. 373. Stems of different habits. How is the stem of each of these plants adapted for carrying on photosynthesis?

Other stems, as those of the dandelion, dock, and plantain, are very short. On these stems the leaves grow in a flat circle or rosette. Other stems grow underground and send up long leaf-stalks upon which large leaves expand, do their work, and then die, leaving the stem well protected in its buried position in the soil. Such stem habits are seen in many kinds of ferns, in the May-apple plant, and in many grasses.

Light-loving and shade-loving plants. Just as plants such as the trees thrive in bright sunshine, other plants can live only in dim light. Thus many of the flowering plants grow in the shade of the forest. If the light-loving plants and the shade-loving plants were to exchange places, both would die.

***Storage of food in plants.** Since green plants manufacture more food than they need in order to maintain life, they must store the surplus. We must remember, however, that the surplus food is stored for the future use of the plant and its offspring. It is not stored by the plant for the future use of man or other animals. We must remember, also, that the storing of food does not represent any planning by the plant. Some plants, for example the onion and the cabbage, store surplus food in leaves.

The asparagus, broccoli, and many others store food in their stems. The carrot, the beet, and the turnip are familiar plants which store surplus food in their roots. The flowering plants store food chiefly in their fruits and seeds. Familiar examples of these plants are such common fruit trees as the pear, the apple, the plum, and the peach, and such common grains as wheat, corn, rye, and barley.

Self-test on Problem XXX–B. (*Do not write in the book.*) 1. Leaves of green plants are always so formed and arranged as to carry on effectively the work of *transpiration.*

2. Name the various plant structures in which plants store surplus food.

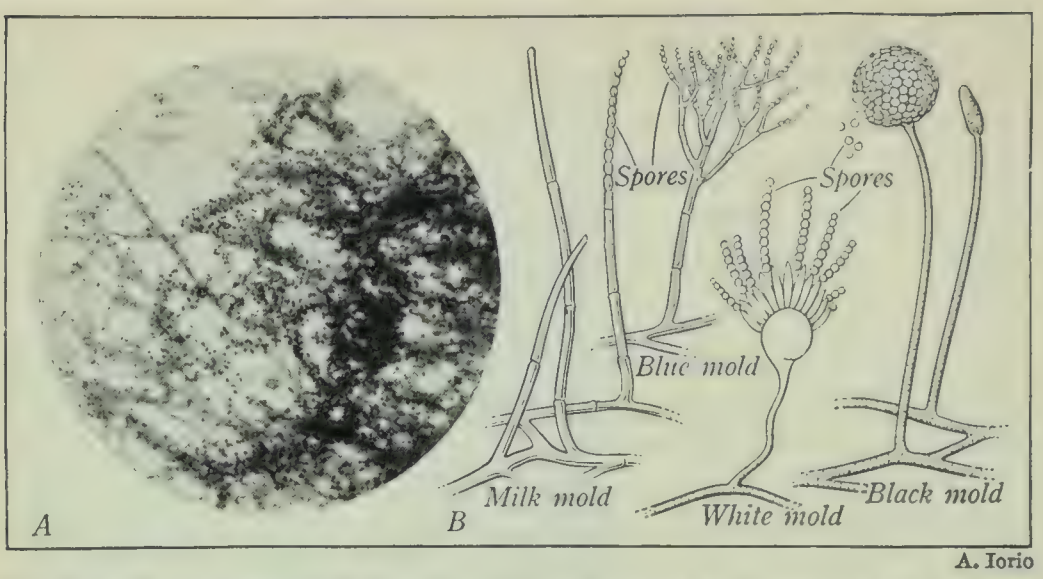
3. *Food* plants store food for the sake of man.

Problem XXX–C · How do Non-green Plants Secure and Use Energy?

Independent and dependent plants. Since green plants can make their own food, they are called independent organisms. Dependent organisms are those that cannot make their own food. Thus animals are dependent organisms, because they must depend directly or indirectly on green plants for food. Certain kinds of plants are also dependent, because they contain no chlorophyll and hence cannot make food for themselves. These plants include molds, yeasts, mushrooms, and bacteria, all of which belong to the large group of plants called fungi (see Glossary).

Experiment 97. Are there living molds and bacteria in air, water, and various kinds of foods? Make an agar-agar or gelatin culture by putting about 100 g. of either agar-agar or gelatin into a quart of distilled water and adding 10 g. each of beef extract, peptone, and salt. Keep the mixture at the boiling point in a double boiler for twenty minutes. Sterilize six Petri dishes by boiling them in water for twenty minutes. Pour a little of the culture into the sterilized Petri dishes and cover these immediately. Allow the cultures to cool before you use them.

Treat each of the cultures in a different way: Put a few drops of milk into one and a few drops of water into another. Press a piece of meat against the surface of the third culture and a piece of cheese against



A. Iorio

FIG. 374. *A*, photograph of bread mold taken under a microscope and enlarged seventy-five times; *B*, diagrams of four common molds. **Special Reports:** Useful molds. Molds that cause diseases. (Consult a textbook of botany or biology or an encyclopedia)

the surface of the fourth. Leave the fifth exposed to the air for twenty minutes or more. Do nothing with the sixth, but keep it with the rest for a control. Cover all the cultures and observe from day to day to note whether any centers of growth of molds and of bacteria develop. Answer with a complete sentence the question at the beginning of this experiment.

***Molds.** When a loaf of bread is left in a warm, moist place for a while, mold appears upon it (Fig. 374). The mold is a threadlike plant which grows through the bread and absorbs its food directly from the bread. After it has grown for a time, some of the threadlike branches grow upward and produce rounded black tips. Inside these tips are many very small cells, or spores. When set free by the breaking of the walls inside which they were formed, the spores cause the odor which is noted when bread has mold growing on it. Each spore is able when it comes into favorable conditions to grow and produce a mold plant like the one that formed it, in somewhat the same manner as that in which a seed develops into a plant. These spores are very light, and so many are formed that they are distributed almost everywhere. They have been found as high as two miles by aviators, who caught them on moist or sticky plates of glass. The spores of bread mold

and of many other kinds of molds are so abundant that molds generally develop wherever favorable food material and favorable temperature and moisture exist. Most kinds of food will become moldy [1] if they are left in an exposed and warm place. Leather clothing, such as shoes and gloves, may become moldy, but the mold on bread and the mold on shoes are not of the same kind. There are many kinds of molds, just as there are many kinds of trees or of insects. They are alike, however, in that they are simple plants, though composed of many cells. Also, they start from spores, grow on food as do other fungi, and, as they grow, reduce the food to simpler elements and compounds.

A few kinds of molds are useful to man, but more of them are harmful, since they consume or spoil food and articles of clothing and since a few cause serious diseases.

Experiment 98. What occurs when mold grows in bread? Place in the bottom of a glass dish a piece of slightly moist white bread which has lain on an outside window sill for ten minutes. Arrange a second piece of bread in the same way and sprinkle on it some dust from the floor. Keep each dish covered with a fruit jar or a piece of flat glass. If mold develops, note and describe its appearance on each of the three following days. Does any substance appear in the dish? What happens to the bread? Explain.

Exercise on scientific method (inventing experiments). Can you devise a test to find whether the mold produces carbon dioxide?

***Yeasts.** Yeasts are extremely small non-green plants. Each plant consists of a single cell. A yeast cell produces a new plant by forming a bud from the old cell. Since a parent plant may have formed several buds, and some of these may in turn have formed buds, it may be that a whole group, or colony, of yeast plants are found together (Fig. 375). Each yeast cell, however, must carry on all its life activities without help from the others.

***Fermentation.** Yeasts get their food from sugar that is in solution. It may be sugar in moist bread dough, in grape juice, or in any other solution. In using the sugar as food the yeasts produce a chemical change in it, breaking it up into carbon dioxide and alcohol. Thus, in bread dough the carbon dioxide gas expands and causes the bread to rise. This makes the pores in the

[1] *Moldy:* full of mold; like mold.

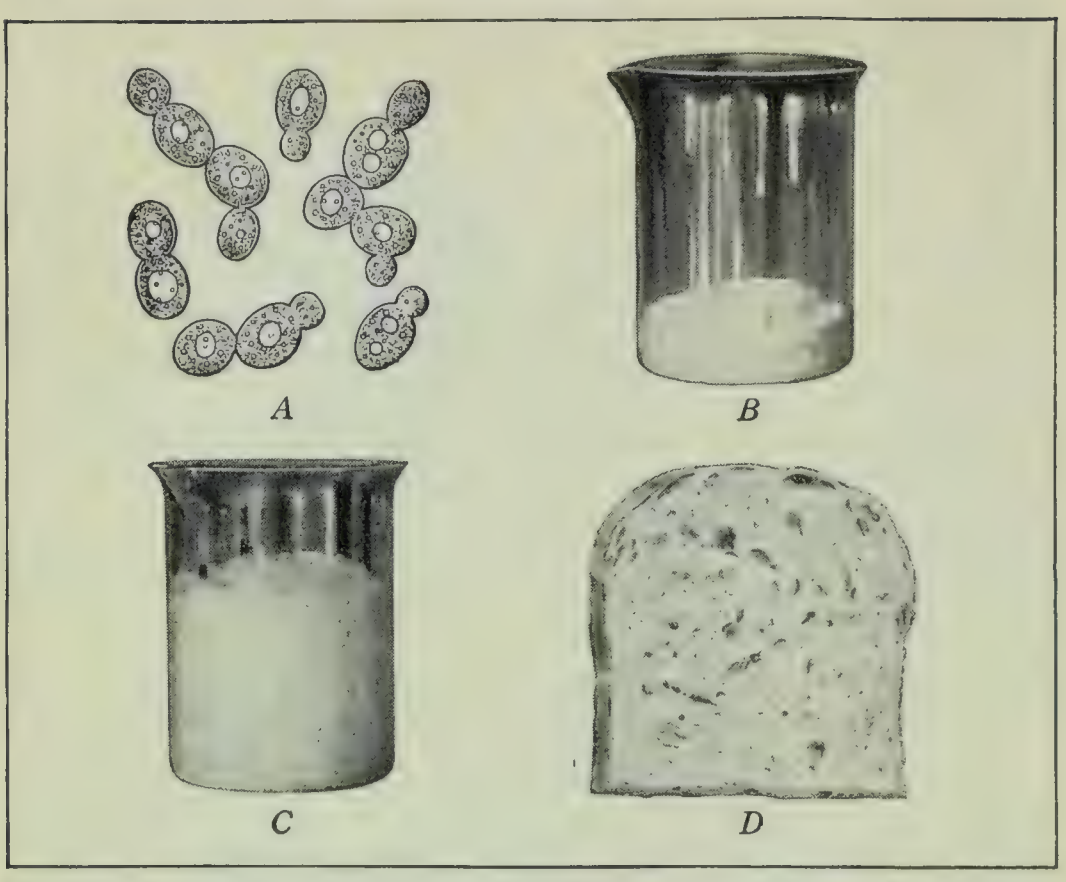


FIG. 375. *A*, yeast plant greatly magnified; *B*, dough in which yeast has just been mixed; *C*, same dough a few hours later; *D*, same dough made into bread. How do you explain the change from *B* to *C*?

bread. Baking vaporizes the alcohol out of the bread into the air. The action of yeast on sugar is called fermentation. Yeasts are so abundant in the air that they are certain to fall into any uncovered substance which is suitable as food for them and to cause it to ferment. Fermentation is, however, also caused by some of the bacteria and by some other fungi.

How mushrooms[1] grow. Most people think of a mushroom as being no more than the stalk and circular top such as is shown in Fig. 376. They are likely not to know about other parts of the plant.

*Mushrooms grow from spores, which are exceedingly small cells. The spores are produced on the ends of threadlike cells in the

[1] It is not uncommon to speak of mushrooms and toadstools as being the same kinds of plants except that mushrooms are good to eat and toadstools are not. In structure they are not different, therefore the name *mushroom* is used in speaking of the whole group.

FIG. 376. *A*, the meadow mushroom, one of the best kinds to eat; *B*, a deadly poisonous kind. Can you see any characteristics by which these might be told apart?

top. Sometimes they are formed on the sides of divisions of the top which hang downward, as in most common mushrooms. Sometimes they are in pores within the top, as in the "shelf fungus" which grows from the sides of trees. Sometimes they are entirely within the top, as in the common fungus called puffball.

*The spores are so small that most kinds can be carried far by the wind. All kinds can adhere to the coats of animals and be carried by them. Different sorts grow on different kinds of living or dead animal or vegetable matter. When they fall where there is the right food and the right temperature and moisture, they germinate.[1] A small white thread is produced, which soon makes many branches. These threads push their way within the organic matter, using part of this matter for their nourishment. Since mushrooms have no chlorophyll, they have to find their food made.

*In favorable weather, when the threads have grown enough, here and there a knot of the threads grows into a lump full of food. What we call the mushroom grows out of this underground food supply. The main life of the plant is underground in the threads that have for a long time been gathering food. The quick-growing mushroom cap is the part in which the spores, or reproducing cells, are formed. In some kinds the threads die after the spores are formed. In other kinds the threads live on and bear their mushrooms in nearly the same place year after year.

[1] *Germinate* (jur'mi nate): begin to grow, as from a spore or a seed.

***Parasites and saprophytes.** Some of the fungi are parasites (Fig. 377); that is, they live in or upon, but at the expense of, other living things which serve as hosts (see Glossary). Examples are the rust of wheat and oats, the smut of corn, wheat, oats, and rye, and the water mold which sometimes kills fish by growing in their gills. Most of the fungi, however, are saprophytes; that is, these fungi live entirely upon dead and decaying things. They aid in decay by breaking up dead bodies and making their material of use again. In this way they greatly increase the fertility of farm, garden, and pasture soils.

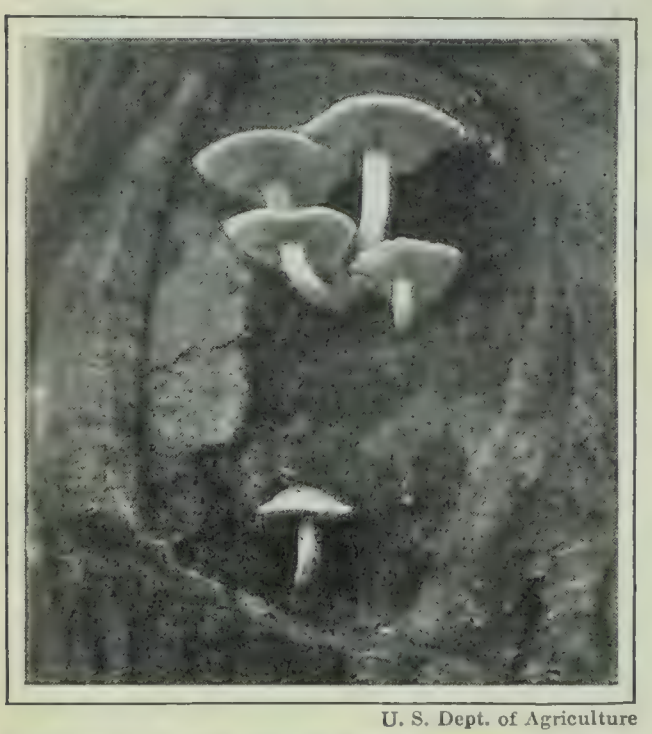


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FIG. 377. A tree-destroying mushroom. How do you think this parasite injures its host?

***Bacteria.** The large group of fungi called bacteria contains both saprophytes and parasites. Bacteria, like yeasts, are one-celled plants. There are many kinds, and all are too small to be seen without a microscope. Some are so small, indeed, that although there is good reason to think that they exist, they have never been seen even by use of the most powerful microscope. This group of plants is known to have lived even when the oldest fossil records of living things were being made.

Experiment 99. Do some kinds of bacteria grow better in bright sunlight or in darkness? Prepare five gelatine or agar-agar cultures in Petri dishes, as in Experiment 97. Inoculate[1] the cultures by touching your fingers firmly to the surface or by coughing into them. Put one of the covered dishes in bright sunlight and beside it put another, but cover the second one with a box or something else which

[1] *Inoculate* (in ok'u late): to plant on a suitable culture microscopic forms. *Inoculation* (in ok u la'shun): act of inoculating.

will completely shut out the sunlight. Examine both cultures after a few days. From your observations of the results, can you answer the questions at the beginning of this experiment?

Experiment 100. Do bacteria grow best in a low, a medium, or a high temperature? Put one culture in its covered dish in the refrigerator or out of doors where the temperature is as low as possible. Put another on the top of the radiator or somewhere else where the temperature is considerably higher than room temperature, yet not hot enough to destroy the culture. Put the third somewhere in the room. Cover each of the three dishes with a box to shut out the light. After several days observe the three cultures. What do you conclude?

Experiment 101. Do bacteria grow better in a moist or in a dry culture? Soak some beans or peas overnight; then put an equal number with a little water into each of two bottles. Cork both bottles and put them away in a closet or in the desk for several days until they become foul-smelling. The foul odor indicates the action of decay bacteria. Then remove the cork from one bottle so that its contents will dry. Again leave both the corked and the open bottle in the desk. Examine both after several more days. What do you conclude?

*In form the bacteria are round (or spherical), curved (or spiral), and rodlike (Fig. 416, p. 624). The spherical forms may be found in pairs or in chains. The rodlike forms are sometimes joined end to end, thus composing a thread, or filament.

Kinds of bacteria. There are many kinds of bacteria. Many kinds live in the soil or in water. Most kinds live upon or within decaying plant and animal material. Several kinds of harmless bacteria are always to be found in the human body. Some of the bacteria found in the intestines[1] may even be helpful unless they are present in extremely large numbers, since they help to break up waste material within the body. Usually, however, when we think of bacteria in the body we have in mind those which produce disease. Only a few kinds, however, cause human diseases. In the main, bacteria are useful agents of decay in that they help to reduce to simpler forms the dead bodies of plants and animals, releasing elements and compounds which may again be used in the food cycle. Certain bacteria aid in the manufacture of butter, cheese, linen, and leather.

[1] *Intestine* (in tes'tin): the tubelike lower part of the digestive system.

Self-test on Problem XXX–C. (*Do not write in the book.*) **1.** Select from the following list the organisms which are dependent and those which are independent: (1) man; (2) cabbage plant; (3) mushroom; (4) cat; (5) fir tree; (6) bread mold; (7) sweet pea vine; (8) bacteria.

2. Molds reproduce from *seeds.*

3. Bacteria, yeasts, and molds have *little* chlorophyll.

4. A *mold* plant consists of a single cell.

5. Most fermentation is caused by *molds.*

6. A louse living on a chicken is an example of a *saprophyte.*

7. A shelf fungus growing on a dead tree is a *saprophyte.*

8. All bacteria are simple, single-celled, very small *bugs.*

9. *More* kinds of bacteria are *harmful* than useful to man.

10. The *stem* is the part of a *mushroom* which produces the spores.

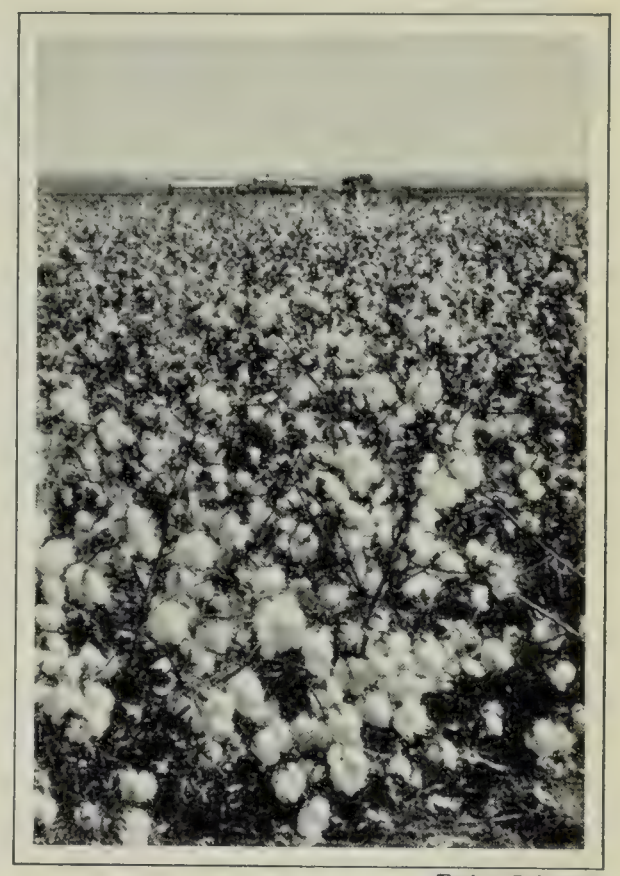
Problem XXX–D · What are Some Important Uses of Plant Materials?

***Plants for cloth cotton.** The cotton plant is the chief source of plant fibers used in cloth-making. As the cotton seed matures, the seed coat is covered by a mass of strong white threads, or fibers (Fig. 378). This is the material from which cotton products are made. Many important industries, industries upon which hundreds of thousands of people depend, have developed because of the cotton fiber. Any disease that affects the cotton plant is of world-wide importance, because the whole world uses cotton in one way or another. Cotton has more to do with clothing the world than has any other living thing. Besides using it for clothing, we make it into cord and cloth for all sorts of uses, we use it as absorbent cotton, we make it into explosives and celluloid and cellophane, and we get oil out of the seeds. The invention of machines for handling cotton, such as the cotton gin and the spinning jenny, has marked highly important stages in the progress of mankind.

Linen. We do not depend on linen for clothing so much as our ancestors did, but it is still important. The flax stem has very strong and fine woody fibers, and if the flax is grown in such ways

that the plants crowd one another for light, the fibers are long and smooth. These are separated from the rest of the stem and made into cloth, thread, or twine. This material is called linen.

Cotton and flax fibers, as well as those of silk and wool, are sometimes mixed with the fibers of the hemp, jute, and a few other plants and woven into coarse cloth. In some tropical countries palm fibers are woven into cloth.



Ewing Galloway

FIG. 378. A cotton field in Texas. Special Report: The invention of the cotton gin

Plants for pulp and for print. Men and other animals make many uses of lint and pulp from plants (Fig. 379). The first books in Europe were written on coarse paper made by pasting together thin strips of the pith of a swamp plant. The Chinese found out that paper could be made by matting together vegetable fibers. By the time that this Chinese invention was brought to Europe the fiber of linen rags was being used. It was after this time that printing was invented. Cotton cloth prepared in several ways has become the common material for binding books. The best quality of paper, used chiefly in personal correspondence and in making special books, is made from linen cloth, usually old. Such paper is expensive. Most books and the newspapers are printed on paper made from wood pulp. The stems of soft-wooded trees, such as spruce and cottonwood, are ground and treated with chemicals until the whole mass of woody tissue is made into a thick paste or pulp. This is then made into sheets of the thickness desired and is dried, wound into huge rolls, and shipped to the printing presses.

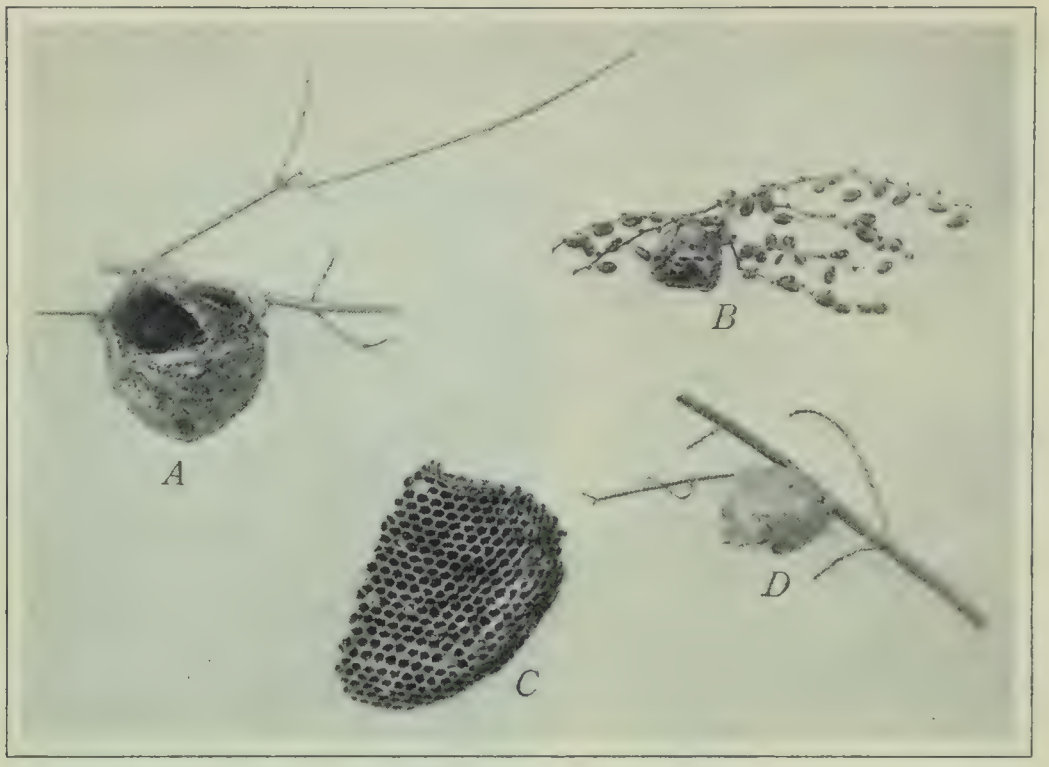


FIG. 379. *A*, vireo's nest made partly from grass and strings and covered with pulp or lint from sticks, boards, and possibly wasps' nests; *B* and *C*, two nests made from lint by black wasps (*B* was fastened to a barberry bush and *C* beneath the roof of a house); *D*, a small nest made from lint by hornets and fastened by them to a tree branch. Special Report: The early history of paper-making

Smaller quantities of paper, expecially brown paper, are made from Manila hemp, straw, wild grasses, cornstalks, and other materials. In recent years small amounts of newsprint paper have been made from cornstalks and from other plants, such as wild grasses, but these sources, though of promise for the future, have not yet provided much of the total pulp and paper supply.

Plant products for special uses: 1. Rubber. It is not possible even to list all the materials in daily use which come from plants. A few will suggest the whole array, and studies of local plant industries should add information.

Rubber found little use until the last half of the nineteenth century. Its greatest use now is in the manufacture of automobile tires. Crude rubber is made from certain juices of many plants which grow in or near the tropics. In one method of producing rubber the bark of the tree is cut through. As the white juice

flows out it is collected and put into a tank in a very warm room. The juice is then allowed to flow from the tank to a whirling disk, which throws off the juice by centrifugal force. The high temperature evaporates the water, allowing the rubber to fall to the floor as a white powder. The rubber is then ready to be made into various products.

The increasing uses of rubber have led the scientists to look for new sources. They have made extensive experiments in growing a wild Mexican plant from the dried trunk of which rubber can be extracted, and have improved the plant so that it now contains more rubber than its wild ancestors. Extensive rubber plantations are already found in California. Further experiments with this plant are being made in the hope of producing offspring that will grow farther north and in regions where there is little water.

Rubber is useful because it can be stretched and compressed and will shed water. After rubber has been in use for a long time or has been exposed for a long time to air, to sunshine, to changes in temperature, and to oil and other substances, it may lose its useful qualities.

2. Tannin. Tannin, or tannic acid, acts chemically upon the skins of animals to produce leather. This process, called tanning, has been known since ancient times. Until recently the bark from oak and hemlock trees was used in preparing the skins of animals for men's uses. The skins and bark were placed in immense tanks and covered with water. The tannin in the bark was dissolved, and the solution helped certain bacteria to grow. As a result of bacterial growth and of accompanying chemical changes, the skins were softened and their structure somewhat changed. In recent times much of the tanning is done by chemically prepared tannin, and the older tanning tanks are not now common. Tannin also finds considerable use in the manufacture of inks.

3. Flavoring extracts. Flavoring extracts are made either from plants or by chemical processes. Vanilla is made from the pods of a tropical climbing plant, the vanilla plant. Coffee, used both as a drink and as a flavor, is made from the seeds of a tropical shrub, the coffee plant. Wintergreen flavor is made from the leaves of the wintergreen plant, a creeping plant common in north-temperate woods.

Keystone View

FIG. 380. Picking rose petals in Bulgaria. Four thousand pounds of buds are distilled to make one pound of attar of roses, which is used in fine perfumes. Attar of roses is now also made artificially. **Special Report:** Perfumes from ambergris and coal tar. (Consult textbooks of chemistry and an encyclopedia)

4. Perfumes. Perfumes as first used by men were substances obtained from a few animals, such as the musk deer, the civet, and the beaver. But thousands of years ago men learned to make more numerous and more delicate perfumes from plants (Fig. 380). At the present time most perfumes are obtained by distilling stems, leaves, flowers, and other parts of plants and then dissolving (usually in alcohol) the fragrant substances that are distilled out. Some of the most delicate ones are made by the older plan of laying flowers on or near a plate covered with fresh fat till the fat has taken the perfume of the flower. Afterwards the perfume can be taken out of the fat by alcohol. But more and more kinds of perfume are being made by synthesis out of coal tar and other chemical materials.

Self-test on Problem XXX–D. (*Do not write in the book.*) **1.** The plant most important in the manufacture of clothing is *linen.*

2. Most paper pulp is made from *cotton.*

3. Rubber is made from the *fibers* of certain plants.

4. Most flavoring extracts are made from various *animals.*

5. *Most* perfumes are produced from coal tar.

Self-test on Scientific Principles. Can you explain and illustrate this principle: "Complex organisms have many different parts and structures, each of which has its own special work to do for the good of the whole organism."

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. The pores through which gases enter and leave plants are in most plants on the under sides of the leaves. In water plants, however, they are on the upper surfaces. How are these different arrangements of the pores of great value to the plants which possess them?

2. In Sequoia National Park, California, is a great sequoia tree, called the Telescope Tree, the heart of which was burned out long ago. One can stand inside the tree at the bottom and look up through the tree at the sky, yet the tree lives. How can you explain this?

3. In a forest the vigorous, taller trees often cause the less vigorous, shorter ones to starve to death. Explain.

4. How many uses of rubber can you list?

5. The leaves of many trees have bright colors in the autumn, yet the materials which produce the colors have been present in the leaves during all the growing season. Can you explain why these bright colors do not show earlier?

6. If one of the potatoes which is being produced by a potato plant is not entirely covered with earth and becomes exposed to the sun, it will turn green. Explain.

7. Potatoes which are stored in a basement will often sprout in the springtime. Often their shoots will grow several feet in length toward a window. Explain.

8. If a strip of bark is cut entirely around a tree, the tree will die. Explain.

9. Sometimes, during the warmest summer weather, the leaves of corn plants curl up and present their edges to the sun. How does this behavior help the plant to endure the heat?

10. Cows and horses eat plants, yet these animals are not parasites. Explain.

11. Can you prove that beefsteak and a glass of milk result indirectly from photosynthesis?

12. How many occupations can you list which depend directly or indirectly on photosynthesis?

13. How are transpiration and respiration related to photosynthesis?

Exercise on Scientific Attitudes. A magazine has printed a story about an African tree which captures and "eats" large animals — even people.

Which of these comments would a scientist consider best? Defend your choice by quoting one of the scientific attitudes (pp. 12 and 13).

a. The story is absurd.

b. Stranger things than that are true.

c. The story is true because I've heard of that tree before.

d. I'll not believe the story until I see the tree.

e. The story sounds silly, but it may be true.

Projects. 1. Make a large diagram of a plant to illustrate as many facts of photosynthesis as you can. Indicate the relation of stem, roots, and leaves to the process.

2. Make a study of different arrangements of leaves and different plant structures of weeds, garden plants, shrubs, and trees which help the plants to secure more sunshine. Draw sketches illustrating each type, and make your report in a form to be a permanent exhibit in the science classroom.

3. Make a diagram, a cartoon, or a drawing similar in purpose to Fig. 370, p. 543, illustrating the water cycle, and including rain, water entering plant roots, transpiration, and the like.

Special Reports. 1. Read in reference books about the relation of bacteria to fermentation, to the making of butter or cheese, and to the preparation of linen and leather, and prepare a class report on one of these subjects.

2. Prepare a list of ten of the animals (mammals, birds, reptiles, or insects) of your region, and show in what sense each is dependent. Show also how its dependence helps or harms other living things.

3. Make an exhibit of descriptions, drawings, or photographs of edible (wholesome to eat) mushrooms which grow near your home. Make a similar one of nonedible or poisonous ones. Consult mushroom books. Be sure not to include among those which are edible any that are in the least doubtful.

Chapter XXXI · Animals Worth Knowing and Studying

Questions this Chapter Answers

On what basis are the various kinds of animals grouped?
What are the characteristics of certain insect pests of the home?
What are the characteristics of certain insects that are useful to men?
Why is insect study valuable?
In what ways are rats and mice serious pests?
In what ways are certain birds helpful, and in what ways are others harmful, to man?
How may birds be encouraged to live about our homes?
Why has our wild life diminished in numbers?
How may our remaining wild life be conserved, and how may its numbers be increased?

Problem XXXI-A · What are Some Insects which Help or Hinder Man in his Struggle for Energy?

***Kinds of animals.** Animal life, or the animal kingdom as it is called by scientists, includes animals which have very great range in structure, size, and habit. Animals, like plants, are distributed through all parts of the world. They range in size from microscopic one-celled animals like the amoeba (see Fig. 358, *A*, p. 525) and the paramecium (Fig. 393, *A*, p. 582) to large and complex animals like man, the elephant, and the whale.

*The difference in size, however, between the largest and the smallest animals is not so important as the differences in structure. In fact animals, and plants as well, are placed in groups not according to size but according to likenesses in structure. Thus all the animals can be considered as belonging in two great groups, the invertebrates, or those that have no backbones, and the vertebrates, or those that have backbones. The invertebrates are the simpler animals. These include such animals as the one-celled ones (Protozoa), sponges, jellyfish, worms, starfish, cysters, snails, spiders, crabs, and insects.

For the sake of convenience in studying the invertebrates they are ordinarily divided into nine great groups, which may be studied in greater detail in a later course in biology. The vertebrates are the highest animals. These include such animals as fishes; frogs and toads (Amphibia); snakes and lizards (reptiles); the birds; and dogs, goats, horses, and man (mammals). Vertebrates have a body built round their jointed bones, which make it possible for a large body to stand and to move about. The highest invertebrates, such as crabs, lobsters, and the insects, have a hard, jointed shell which gives them some but not all of the advantages that vertebrates get from having bones.

FIG. 381. How many mammals can you name in two minutes?

*The highest vertebrates, which include man and the hairy or furry four-footed animals, are called mammals, because they produce milk with which to feed their young (Fig. 381).

At present the animals which are most numerous and also most harmful to man are the insects. Some of the insects which are generally useful or harmful will be discussed now. Those which by their activities affect gardening and farming will be discussed in Chapter XXXVI.

Harmful insects: 1. The housefly. One of the most dangerous insects to man is the common housefly. It is known to carry the germs of such terrible diseases as typhoid fever, tuberculosis, diphtheria, and many others. It is thus indirectly responsible for the deaths of many thousands of people every year.

The life history of the fly, like that of most insects, has four stages: egg, larva, pupa, and adult (Fig. 382). The eggs are laid in manure, garbage, or in fact in almost any kind of decaying

A. M. N. H.

FIG. 382. *A*, the four stages in the life history of the housefly; flies develop in places like *B*. Why is a "clean-up campaign" more effective as a means of getting rid of flies than either a fly-catching or a fly-killing campaign?

organic matter. They hatch into larvae in about ten hours. Five days later the larvae enter the pupal stage, and after remaining as pupae for from five to fifteen days, emerge as adult flies. Within another two weeks they are able to lay eggs.

Getting rid of the housefly. The most effective way to get rid of the fly is to prevent its breeding. Garbage should be kept in metal cans with fly-tight covers. These cans should be washed frequently and thoroughly and then rinsed with boiling water. Borax and chloride of lime should be sprinkled on manure piles, on rubbish heaps, and in open toilets. Flies cannot breed in dry materials. Therefore if manure is spread on the fields in a thin layer which the sun and air can quickly dry, the young flies in it will die. Flies can be poisoned by leaving open dishes of milk to which have been added a little sugar and formaldehyde in the proportion of two tablespoonfuls to every pint of milk. Such poisoned milk, however, should be kept where it cannot be reached by children. A female fly may lay more than five hundred eggs and may have several generations of descendants[1] in a single season. Therefore the war on flies should be begun in May or at latest in early June. Killing one fly in the winter or early spring is more effective than killing several million in August.

[1] *Descendants* (de send'ants): successive generations of children.

2. Ants. Some kinds of ants are serious pests.[1] They invade kitchens in search of food. Ants have developed community life almost beyond the belief of those who have not studied them. They have constructed extensive homes underground or in trees, with rooms for different uses, and with different ants assigned to the care of the different parts of the home. An ant community has its queen ant, which alone can lay eggs to provide future members of the colony; nurse ants, which care for the eggs and young ants; soldier ants, which guard the entrances or go out to fight enemies; workers, which go hunting for food and bring it back for the common use of all. In some ant communities, which store food in the form of sweet substances almost like honey, the food is fed to certain ants which hang from the roof of small rooms within the home. A storehouse ant swallows honey till its body is stretched into a round bag with a head and legs at one end. When the other ants need food they come for it and cause the storehouse ants to give up part of the food. Some ants even plant fungus spores upon cut leaves of plants, and in darkened rooms within the earth thus grow their own molds or mushrooms for food. These are but a few of the facts one may learn by a study of ants.

3. Insect pests of the household. Insects such as clothes moths, bedbugs, and buffalo beetles (Fig. 383) are common in sleeping and living rooms. The moth lays its eggs on woolen cloth or on furs. The egg hatches into the larva. The larva eats the wool. When it is ready for its resting stage it makes its cocoon from the woolen material.

Bedbugs live in blankets and quilts and in the cracks of beds. Buffalo beetles live in carpets and in the cracks in the floors and the walls. Both of these pests may be disposed of by thoroughly washing the floors and walls, by placing the blankets, quilts, and carpets in the sunshine out of doors, and by thoroughly treating the beds and the floors with poisonous washes and insect powders.

Helpful insects: 1. Bees. There are many kinds of bees. The most familiar are bumblebees and honeybees. Both are useful and merit study and care. Bumblebees visit the flowers of field crops

[1] *Pest:* something that injures or annoys.

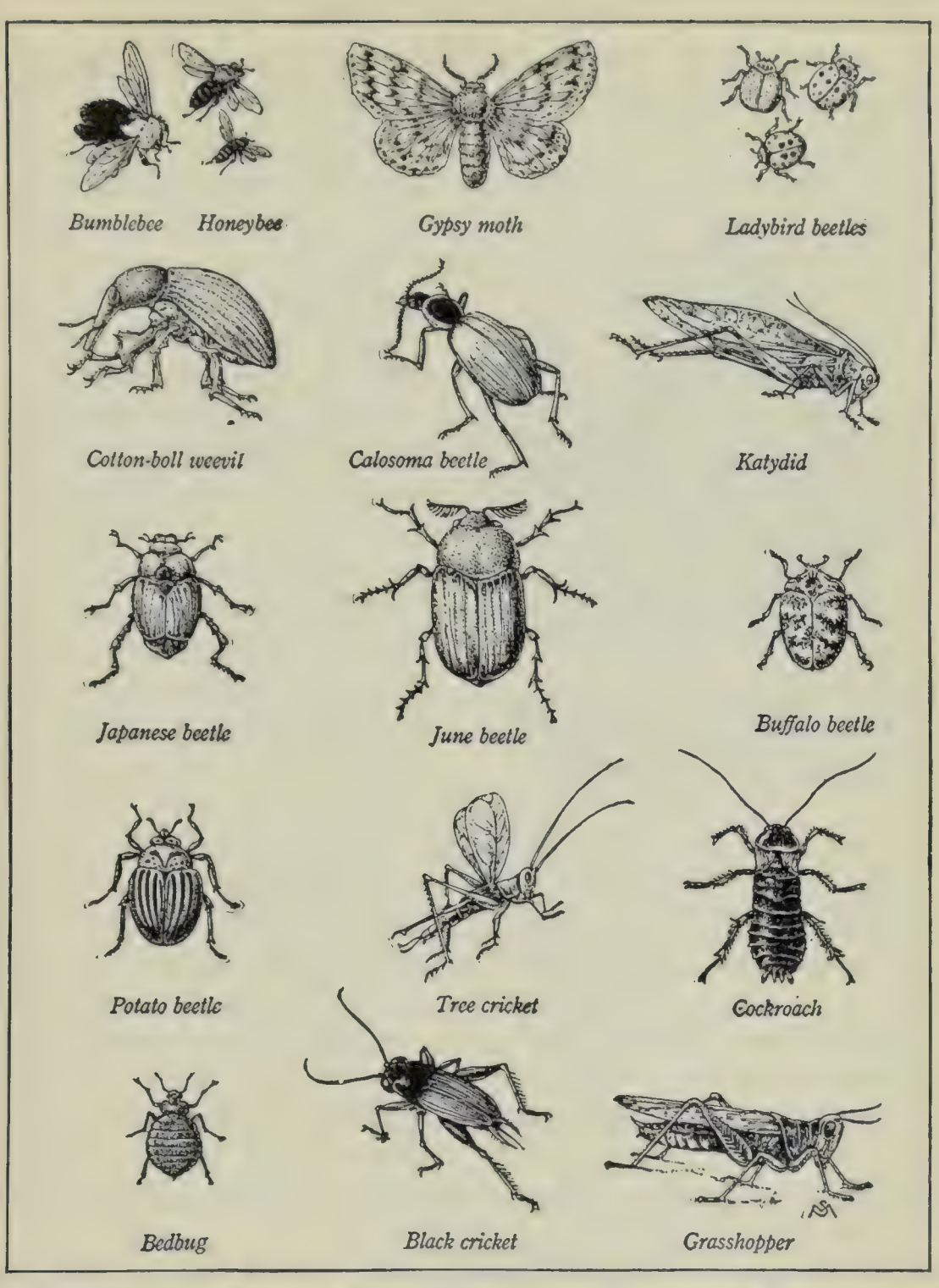
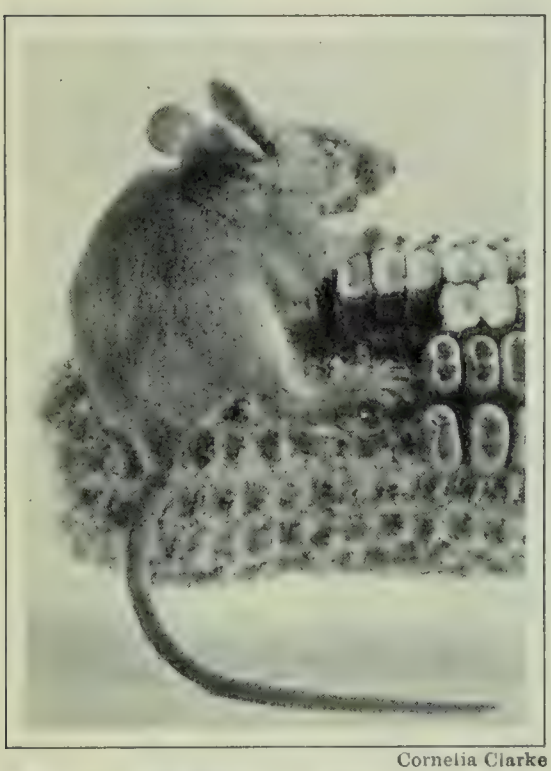


FIG. 383. **Special Reports:** Which of these insects are helpful and which are harmful to man? (Consult insect books, textbooks on biology, and bulletins from the Federal or Dominion Bureau of Entomology or from your state or provincial agricultural experiment stations.) **Exercise on Scientific Method (Evaluating Conclusions):** From a study of this figure should you conclude that all insects have six legs? Explain

in search of nectar, a sweet substance which is produced in flowers and which bees make into honey. In so doing they carry pollen from one flower to another, thus helping to distribute the pollen necessary in forming the seeds.



Cornelia Clarke

FIG. 384. Self-test on Scientific Principles: Can you explain how this picture illustrates the principle "There is constant competition among living things for the available food supply"?

A good hive of honeybees may store up two hundred pounds or even more of honey during a season, in addition to the amount required to care for the needs of the bees themselves.

Honeybees have a community organization somewhat like that of ants. One who studies bees and cares for them properly is likely to receive a good return for his efforts.

2. Silkworms. The silkworm is the larva of a moth. After hatching from the egg the larva feeds for about a month on the leaves of the mulberry tree. It then spins its cocoon and rests within the cocoon as a pupa for about two weeks. It then emerges as an adult. The adult moths never eat. They die within a few days after leaving the cocoon. First, however, they mate and the females lay their eggs. The life cycle — larva, pupa, adult, egg — is repeated the following season.

Silk thread is woven from the silk strands of the cocoon. The silk moths are raised chiefly in Japan, China, Italy, and France, but much silk cloth is woven in the United States.

The need for studying insects. The few illustrations here given of harmful and useful insects will indicate the importance of insect study. We see its importance better when we realize that there are more kinds of insects than of all other kinds of animal life

combined; and still better when we realize that, with the almost unlimited possibilities of reproduction among insects and with the wide range of their food supply, we do not know how to keep some kinds from destroying the things upon which we human beings depend. They eat our food and our clothes, they live in our homes, they attack our flowering plants and food crops, and do many other kinds of damage.

If men do not learn how to solve the insect problems, they will suffer in many ways, and possibly may starve.

Other animals in relation to health and comfort. Rats and mice are often serious pests (Fig. 384). They eat both fresh and stored food of almost all kinds, and spoil part of the food they do not eat. Rats are known to be carriers of the germs of bubonic plague and may possibly carry other germs. Fleas and other insect pests which carry disease germs are commonly brought to our homes by rats and mice.

Self-test on Problem XXXI–A. (*Do not write in the book.*) **1.** The plants and animals are put into the *same* groups if they are closely alike in *size.*

2. The higher animals are *invertebrates.*

3. *Few* of the invertebrates feed their young on milk.

4. An example of an animal which has a skeleton on the outside of its body is a (1) mammal; (2) bird; (3) beetle; (4) amoeba; (5) snake.

5. Select from the following animals those which are harmful to man and those which are useful to man: (1) houseflies; (2) bees; (3) silkworms; (4) ants; (5) bedbugs; (6) clothes moths; (7) rats; (8) mice; (9) fleas.

6. Which, if any, of the animals in the preceding list are mammals?

Problem XXXI–B · How are Certain Birds of Interest and Value to Man?

What some birds eat. Birds are chiefly helpful or harmful to man because of their feeding habits. A nest of house wrens three-quarters grown (Fig. 385) were brought food by their parents one hundred ten times in four hours and thirty-seven minutes. Not all the kinds of food could be recognized while the feeding was being watched, but that which could be seen included one

FIG. 385. *A*, a mother chickadee and her four young ones; *B*, a mother wren and a young one. **Self-test on Scientific Principles:** Can you explain the relation of the feeding habits of birds to the matter cycle and the energy cycle?

hundred eleven insects and spiders. On the next day the nest was watched again, and the young birds were fed sixty-seven times in three hours and five minutes. Another nest of house wrens was fed seventy-one times in one hour, an unusually rapid rate of feeding.

In feeding young chickadees (Fig. 385) the parent birds were observed to make six visits in thirteen minutes. The parent birds carried several small insects on each visit. On examination it was found that they were feeding their young with ants, plant lice, and spiders.

Birds which help or harm. One yellow-billed cuckoo (Fig. 386, *B*), commonly called rain crow, ate 217 fall webworms, and another ate 250 tent caterpillars. Tent caterpillars eat the leaves of fruit trees, and in spring make tentlike homes where the branches come together. Webworms make a web all over a branch of a tree in the fall, and devour all the leaves inside the web.

FIG. 386. *A*, nighthawk catching a mosquito; *B*, yellow-billed cuckoo eating tent caterpillars; *C*, flicker eating black ants; *D*, screech owl with a mouse. Which of the following statements is correct and why: "These birds do all they can to help man," or "Man benefits from the activities of these birds"?

One nighthawk (Fig. 386, *A*) ate 60 grasshoppers, another ate 500 mosquitoes, and a third ate over 1000 ants. A bobwhite, or quail, ate about 1700 weed seeds in one day.

Flickers are known to eat large numbers of black field ants (Fig. 386, *C*). These ants injure the roots of corn because of a most peculiar habit: they like to eat the sweetish fluid made by certain kinds of plant lice. The plant lice live on the sap which they suck from the tender roots of corn and grass. The ants dig dens in the soil down to the roots of the corn, then carry the plant lice down

FIG. 387. Female warbler (left) and her nest. The smaller eggs are hers, the larger ones are cowbirds' eggs. The bird at the right is a male cowbird. **Exercise on Scientific Method (Making Inferences):** How do you explain the fact that the male and female warbler built their nest three times?

through these dens and put them on the corn roots. When the lice get plenty of sap they produce the sweet substance which the ants like. More flickers means fewer black field ants; fewer black field ants means fewer plant lice. Fewer plant lice means less injury to corn. Less injury to corn means better crops. Better crops means more successful farms. More successful farms should mean more chances for farmers' children. We can see, then, how much depends on the help of birds like the flicker.

*__Most birds are helpful.__ Such studies, made by many workers, show that only a few birds are harmful much of the time and that almost all are useful most of the time. Some birds, such as the crow, the blue jay, and the cowbird (Fig. 387), however, are probably more harmful than useful to man, though they devour harmful insects. Crows and blue jays destroy the eggs and young of other kinds of birds. Cowbirds make no nests but, like a few less common birds, they lay their eggs in the nests of smaller

birds. Then after the cowbird young are hatched, they greedily reach for all the food that is brought and soon are large and strong enough to push out of the home the young birds that belong there. In this case no favor is returned for the help received, but much harm.

Where and when the birds go. The constant need for food causes nearly all our common birds to migrate; that is, they move southward in the autumn and northward in the spring. People watch for the first birds in the spring and sometimes keep records of their return. Usually we do not note the autumn migration until we are suddenly aware that the birds are gone. In both the spring and the autumn we may see northern birds passing through the temperate zones, some making short stops to feed and possibly to rest. By careful listening at night in spring and again in autumn we may hear the flocks of various kinds as they speed on their long journeys.

Encouraging birds to live with us. The value of birds for their beauty and for their songs is beyond estimate even if we do not consider their value as eaters of insects and of weed seeds. Much can be done that will encourage them to live about our homes. Bird-feeding is especially desirable during the winter. Feeding-shelves on the windows or on posts will attract many birds if kept well supplied with grains and seeds in abundance and variety. A ball of suet tied securely to a tree limb will attract others. Birdhouses and a bird bath offer additional attractions which can be supplied at small expense and with little trouble. Birds should be given as much protection as possible from cats and other enemies (Fig. 388).

Self-test on Problem XXXI–B. (*Do not write in the book.*) **1.** Man derives benefit or harm from birds chiefly because of the kinds of *nests* they *build*.

2. Select from the following birds those which are more harmful than useful and those which are more useful than harmful: (1) flicker; (2) crow; (3) chickadee; (4) nighthawk; (5) wren; (6) blue jay; (7) cowbird.

3. Many of our native birds go *north* when cold weather approaches.

4. A bird which does not hatch its own young is the __(?)__.

FIG. 388. Two enemies of songbirds. *A*, cat on a tennis-court fence, eating a bird it has caught; *B*, red squirrel, which eats birds' eggs and young birds. Can you suggest ways of protecting birds from these enemies?[1]

5. It is not possible to remove all the dangers to birds that nest about country homes, but they can be helped by destroying or driving away the __(?)__ and the __(?)__.

Problem XXXI–C · Of What Importance are the Conservation and Care of Animal and Plant Life?

Our diminishing wild life. The first settlers found this country full of wild animals and suffered much damage from them. The bear, the panther, the wolf, the fox, the mink, the hawk, would kill the farmer's chickens or pigs, sometimes a calf or a colt. The deer and the rabbit would eat his crops. On the other hand, he needed the animals' flesh for food and their fur for clothing. Thus he had two reasons for killing the wild animals of which the woods and plains were full: (1) he must protect himself

[1] *A*, courtesy of the National Association of Audubon Societies; *B*, courtesy of the Department of the Interior, Canada.

Hillman

FIG. 389. Rocky Mountain goat, Glacier National Park, Montana. **Self-test on Scientific Principles:** Explain how this picture illustrates the principle "Many animals are colored in such a way that they blend with their environments (see Glossary) with the result that they are difficult for their enemies or their prey to see." What other animals do you know that have protective colors?

against them and (2) he must use them as supplies for his needs. As the country was made into farms, and towns grew up, there was less danger from harmful animals and less need to hunt animals for food.

But hunting for pleasure or because of the desire to kill has gone on until it has become needless and cruel destruction of wild life. Along with this practice there has developed an added danger to the animals. As the country became settled the kinds of homes in which many of the wild animals had produced their young were slowly destroyed. For example, the buffalo could not roam over the plains after the plains were fenced and plowed. The diminishing forests no longer provided abundant nesting and hiding places for the thousands of living things that they once contained.

***Conservation of wild life.** The United States government, the Canadian government, and most of the state and provincial governments now have laws known as game laws to protect certain kinds of birds and other animals. For example, one cannot

FIG. 390. A shop window in a large city. Special Report: How does your community take care of its animals?

kill deer, wild duck, quail, or many other animals except during certain short periods, if at all. Moreover, in many states laws have been passed protecting the native wild flowers.

*Great areas of national and state parks, or forest preserves, have been established, partly to help toward protecting wild life (Fig. 389). These parks are the people's playgrounds and are places for pleasure and for learning about nature. They are proving of great importance in saving and increasing wild plants, as well as animals of many kinds, which would otherwise soon disappear.

Keeping animals for pleasure and profit. A farm without tame animals of some kind is hardly to be found. In the earliest history of human civilization there are pictures of animals as companions of men. Men seem always to have had an interest in animals, whether for work or for food or for pleasure. Even in the crowded city today animals are kept as pets (Fig. 390). Sometimes, however, animals are kept in cities with so poor care, so little open air, and so little thought of an animal's good health that the right to keep them must be questioned. It seems fair to insist that any person who keeps a pet should provide such conditions for it as will enable it to live comfortably.

Self-test on Problem XXXI–C. (*Do not write in the book.*) **1.** In pioneer times there were *fewer* wild animals than now.

2. In national and state parks both __(?)__ and __(?)__ are protected.

3. Most animals can live more comfortably in the *country* than in the *city*.

4. Hunters have greatly *increased* the number of wild animals.

Self-test on Scientific Principles. 1. Can you illustrate this principle from the materials in this chapter: "Living things are constantly striving against each other for the available food supply"?

2. How does an owl which catches and eats a mouse or rat help human beings to survive? How does this question relate to the principle "All living things are helped by the activities of some other living things and are harmed by the activities of still others"?

ADDITIONAL EXERCISES AND ACTIVITIES

Exercises on Scientific Attitudes. 1. As Jane and Alice were walking to school one fall morning, Alice suddenly cried out: "Look at that horrid yellow spider! Step on it!"

"Oh, no. Don't hurt it," said Jane, holding out her hand for the big golden-yellow spider to crawl into it.

"Look out!" cried Alice; "it will bite you! You wouldn't get me to touch it — not for anything!"

"It won't hurt you. It's not that kind of spider. It is a beauty! There are very few poisonous spiders, outside of tarantulas and black widows. You can recognize the black widow by the red patch shaped like an hourglass on the abdomen. I wouldn't touch a black spider, but others are harmless. Here, you hold it."

"Ugh, no!" said Alice, shrinking back. But when she saw Jane laughing at her she finally held out her hand timidly. The first two times Jane put the spider on her hand Alice dropped it, but the third time she kept it and soon lost her fear of it.

"I'll tell you," said Jane, "let's take it to school and look at it under the magnifying glass. You've no idea how funny and interesting spiders' heads and mouths are."

The surprising fact was that when, a few minutes later, a crowd of boys and girls gathered round Alice and Jane to look at the spider, Alice's enthusiasm was as great as Jane's. She had forgotten that a short time before she had called her "yellow beauty" horrid.

Which of the scientific attitudes (pp. 12 and 13) are illustrated by this story?

2. A very vicious bull attacked a man in a red sweater who was crossing the pasture. The man concluded that the bull had attacked him because of the red sweater. Do you accept or reject the man's conclusion? Support your decision by quoting one of the scientific attitudes.

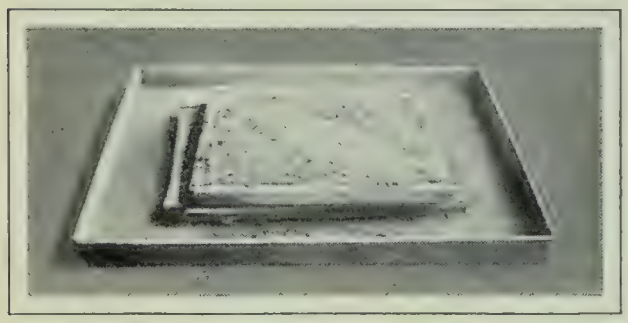


FIG. 391. An ants' nest for study indoors. **Special Report:** The destructive activities of termites. (Consult bulletins from the Bureau of Entomology)

Projects. 1. To present the work with animals which your class is doing. Arrange a school exhibit with a description of all the animal pets kept by members of your class. Build suitable display cages for some of the pets and include these pets in the exhibit.

2. To study an ants' nest in the schoolroom. Transfer as much of the ants' nest as you can to a deep pan (Fig. 391). Place this on a board and put the board in a large pan the bottom of which is well covered with water to prevent the escape of the ants. Transfer the large pan to your schoolroom. Keep a careful record of the activities of the ants. Try to find what kinds of food they will eat.

Special Reports. 1. The migration of the golden plover, a near relative of some of our common water birds, is especially interesting (Fig. 392). Its story will illustrate the kind of study which may be made of many of our migrating birds.

If (as is the common understanding) an animal's home is where it makes its nest and rears its offspring, then the home of the golden plover is in the northernmost part of North America. Arriving here between the middle of June and the first days in July, the birds at once make shallow nests on the ground, using a few leaves or a little dead grass as building materials. Here are laid four (occasionally five) yellowish-olive eggs, each about one and a quarter inches thick and about two inches long. In six weeks the eggs have hatched, the young birds have grown to full size, and their wings have been given trial and exercise.

All the flocks of old and young birds then begin to move southeastward, feeding on the abundant insect life as they go. The old birds go ahead, and the younger ones follow. Late in August the flocks have reached Newfoundland and Nova Scotia. They have eaten vast numbers of insects and are fat and strong. Then comes one of the wonders of animal life. The advance flock rises and starts for South America,

followed for days by succeeding flocks of their own kind. In good weather the birds are thought to fly, without stopping, not less than three thousand miles. They land in two or three days, thin and tired, and ready to feed and rest in the plains of Argentina in South America. When storms are along the Atlantic coast, many birds are blown to land. Indeed, when there are no storms a few birds are sometimes found along the North Atlantic coast. Years ago in times of ocean storms, in late August or early September, thousands of these birds were killed by hunters from Long Island to Newfoundland. Even today hunters search the coasts for any golden plover unfortunate enough to be driven to the shore within the range of their guns.

FIG. 392. Migration of the golden plover. What birds spend their winters around your home?

After feeding in Argentina for a few months the plovers begin the journey northward, a long, slow feeding trip over the plains of South America. By early spring the flocks are south of the great forests of South America. Being birds of swamp, shore, and plains, they now rise again and fly northward over the forests. Early in March they arrive on the plains of Texas and other south-central states, again thin and tired from a long flight. Then they again move and feed slowly, working northward through the Mississippi Valley, devouring insects in great numbers.

They eat grasshoppers, locusts, crickets, cutworms, wireworms, and other small animal life. They devour these insects in springtime, thus doing much good by killing off the parent insects of what might have been large families of destructive insects. This slowly advancing insect-feeding army of golden plovers, spread wide over fertile plains, goes northward from March to June. In June the plovers reach their home, and the cycle begins once more.

What local birds migrate? Can you find their stories in bird books? The Audubon Society (New York City), the Bureau of Conservation (Washington, D. C.), and your own state agricultural school may be able to furnish you information concerning some of the birds.

2. Learn from your state or provincial department of conservation what bird-banding is being done in your state or province. Describe how bird-banding is done.

3. Secure from your state or provincial game commission or state or provincial secretary copies of your laws regarding the protection of birds and other wild animals, and prepare a class report on this topic.

4. Prepare a report to be made in your science class on some part of Maeterlinck's *The Life of the Bee.*

5. What are termites? What sorts of damage do they do? Are they advancing into new parts of the country? What can be done to combat them? (Secure information from the Bureau of Entomology, Washington, D.C.)

Questions for Debate. 1. *Resolved,* That plants are directly more useful to man than animals.

2. *Resolved,* That laws should be passed to prevent people from keeping cats.

Books for Reference

Comstock, John H. The Spider Book. Doubleday, Page and Company, New York.

Hornaday, William T. American Natural History. Charles Scribner's Sons, New York.

Holland, W. J. The Butterfly Book. Doubleday, Doran & Company, Inc., New York.

Holland, W. J. The Moth Book. Doubleday, Doran & Company, Inc., New York.

Chapter XXXII · Continuing and Improving Living Things

Questions this Chapter Answers

What are asexual reproduction and sexual reproduction?
What common methods of asexual reproduction are observed in simple plants and animals?
How is sexual reproduction illustrated by a flowering plant?
How is sexual reproduction accomplished in higher animals?
Do most kinds of living things produce few or many offspring?
What conditions limit the numbers of any kind of living thing?
How is a "balance of life" maintained?
What is meant by an inherited character?
What are freaks and mutants?
How do variations affect survival?
What are laws of heredity, and how can these be applied in improving plants, animals, and man?
How are heredity, environment, and training related to one another?

Problem XXXII–A · How do Living Things Reproduce?

The simplest reproduction. If you were to watch through a microscope a single-celled animal such as an amoeba or a paramecium, you might see it go through several changes and finally divide into two animals like the first (Fig. 393, *A*). Thus two complete new animals would be formed from one. An amoeba or a paramecium is neither a male nor a female. Reproduction of this kind is known as asexual reproduction or reproduction without sex.

Methods of asexual reproduction. There are several methods of asexual reproduction. Most of the simplest animals and plants have no sex. Hence they reproduce by one or more of these methods: In some cases a single animal or plant will produce two new ones, as in the manner just described. In other cases a plant or an animal will form buds, which will develop and finally separate from the parent, and each will develop into a new organism like the parent (Fig. 393, *B* and *C*). In other cases an

organism will at one time produce many like itself (Fig. 393, *D*). In still other cases a complete new plant or animal will grow from

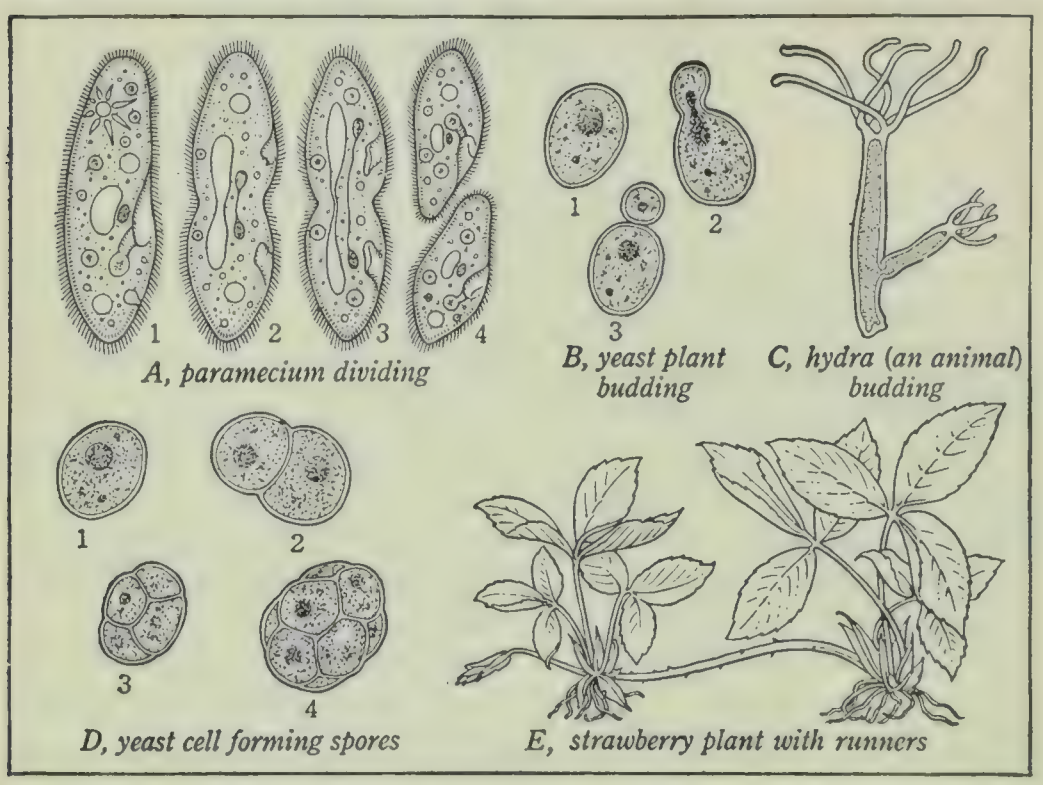


FIG. 393. Four methods of asexual reproduction by plants and animals. How do these methods of reproduction differ from ordinary growth?

a part of a mature parent. An experiment with a geranium plant will serve to illustrate this last method of asexual reproduction.

Experiment 102. How can a new geranium plant be produced from a part of a mature plant? Separate two or three of the branches from a healthy geranium plant. Insert the stem ends of these pieces three inches into moist sand. Keep the sand moist. After several weeks examine the ends which have been buried. Have any roots formed? If so, plant the young plants in rich moist soil, water them from time to time, and observe whether they develop into complete geranium plants.

This method of asexual reproduction is known as vegetative reproduction. It is widely used in producing garden and orchard plants of many kinds. Roses and grapes usually reproduce readily from such cuttings. Yet another method of reproduction from a single parent which is much used in agriculture is illustrated by the black raspberry and the strawberry (Fig. 393, *E*). When

certain parts of the stems of these plants touch the ground, they commonly take root and develop complete new plants. Such young plants can then be transplanted.

Grafting and budding. New fruit trees of many sorts are produced by a method of vegetative reproduction similar to the one just described and known as budding and grafting. There are many different ways of budding and grafting, but they all differ from each other so slightly that the following general description fits them all. A branch or stem containing a bud is cut from a plant of the desired kind. This cutting is planted, not in the ground, but in the branch or stem of another plant. The growing layer of the cutting is placed against the growing layer of the stem or branch upon which it is grafted, for in this way only can the new branch be made to grow and to join the living tissue of the old plant. The place where the two are joined is covered with wax or is tied so that the cut surfaces join firmly and also so that moisture will not evaporate from the wound. Budding or grafting is applied in growing most of the best varieties of fruit trees, nut trees, and foliage trees.

Sexual reproduction. You are familiar with the fact that a young dog or cat has always two parents. Such an offspring is either a male or a female. Reproduction resulting from two parents is called sexual reproduction. It is the method of reproduction of all the higher animals, of the higher plants, and also of many of the simpler animals and plants. This method of reproduction can be illustrated with any of the typical flowering plants.

***Sexual reproduction in a flowering plant.** The essential structures of a flower are (1) the central part or pistil (Fig. 394), in which are one or more ovules, and (2) the stamens, which stand next to the pistil and in which the pollen is formed. The ovules contain the female cells. The enlarged part of the pistil is called the ovary, since the ovules develop within it. It is in the pollen that the male cells develop. As has already been stated, pollen is carried from flower to flower on the feet and bodies of bees, butterflies, and other insects. Pollen is also carried by the wind. One or more pollen grains may fall upon the tip of the pistil, and from this pollen grain may grow a small tube in which the male cells are carried to the egg (or female) cell, which is within the

ovule. The male cell of the pollen and the female cell of the ovule unite, forming a new cell called the embryo. There are other special parts and processes that are related to the forming of seeds. These are more fully presented in a later study, biology.

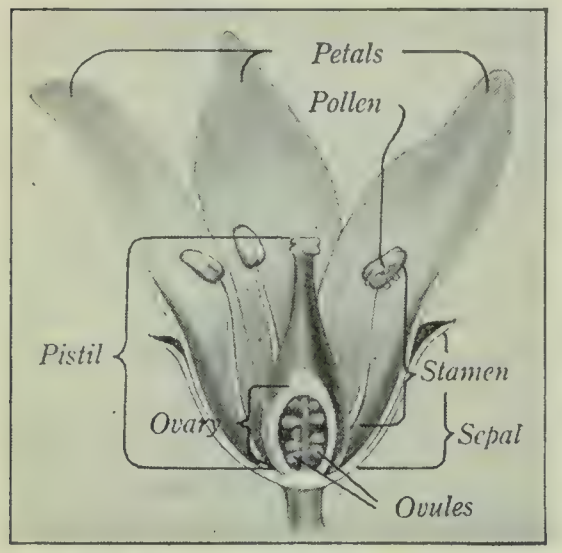


FIG. 394. A complete flower has four parts: (1) the outer leaflike sepals, which together are known as the calyx; (2) the inner, usually brightly colored petals, which together are known as the corolla; (3) the stamens; and (4) the pistil. Some flowers, known as perfect flowers, have only those parts necessary for reproduction. Which two do you suppose that they have? Explain

The embryo grows and develops the parts of a new plant while still within the ovule. Food is stored by the parent plant around it. The ovule containing the embryo and the stored food becomes a seed.

The fruit. The ovule wall may become hard and dry, as is true in many ripe seeds, or it may become a pulpy[1] fruit, or the whole pistil and sometimes the flower stem itself may become a pulpy fruit. The seeds and whatever parts ripen with them are called the fruit. For example, in an apple the ovules ripen into the shining seeds found in the middle, the wall about the ovules becomes the core of the apple, the outer part of the pistil becomes the inner part of the fruit, and most of the apple is the swollen lower part of the green outer leaves of the flower, whose withered tips are seen at the blossom end of the fruit. In the strawberry the tip of the flower stalk has pistils all over it. As the seeds ripen, this tip swells upward between the seeds. The seeds are in small pockets in the ripening stem tip. Thus the ripe strawberry is the enlarged stem tip with the seeds.

Fruits a source of food. Plant food stored by a plant in its seeds is normally used as the seeds sprout. It nourishes the young plants until they have developed sufficiently to make their own

[1] *Pulp:* a soft, moist mass. *Pulpy* (pul'py): pulplike, full of pulp.

food by photosynthesis. But often man and other animals rather than young plants use this stored food. All the grains — wheat, corn, oats, barley, rye, and rice — are valuable to us because of food stored within the seed round the young plants. The nuts, such as walnuts, almonds, pecans, and filberts, have rich foods within the seeds. The young plants are enclosed by the hardened skin of the ovule, and this in most nuts by a wall made from the pistil. Tomatoes, apples, peaches, melons, oranges, and berries are valuable to us because of the plant food stored outside the seeds. The young plants of these kinds, however, make no use of this pulpy food outside the seed. There is another supply within the seed which they use.

Reproduction in higher animals. In sexual reproduction with animals, as with some plants, an enormous number of small, active male cells (sperms) swim to relatively large female cells (ova). A sperm unites with an ovum, fertilizing it and producing the embryo. The embryo begins as a single cell. It grows and divides again and again, forming additional cells, and later forms all the various structures and organs. With animals such as fish and toads the ova are fertilized outside the female's body. With animals such as snakes, birds, and mammals, as well as many lower forms, the sperms are deposited by the male directly in the female's body. With animals that lay eggs, such as birds, some snakes, fish, insects, and many others, the embryo develops outside the female's body. It is nourished by food stored in the egg. With some snakes, all mammals, and some other animals the embryo develops within the body of the female and is born alive. The embryo is nourished by food from the mother's blood, which flows to the embryo through the tube by which the embryo is attached to the mother.

*Summary. Reproduction takes place only when some portion of a living thing separates from the parent and continues to develop independently into an organism which resembles the parent. In animals and plants there are two types of reproduction, asexual reproduction and sexual reproduction. Asexual reproduction occurs with plants and animals which have no sex. These are mostly the simpler organisms. Sexual reproduction occurs with organisms having sex. These are chiefly the higher plants and the higher ani-

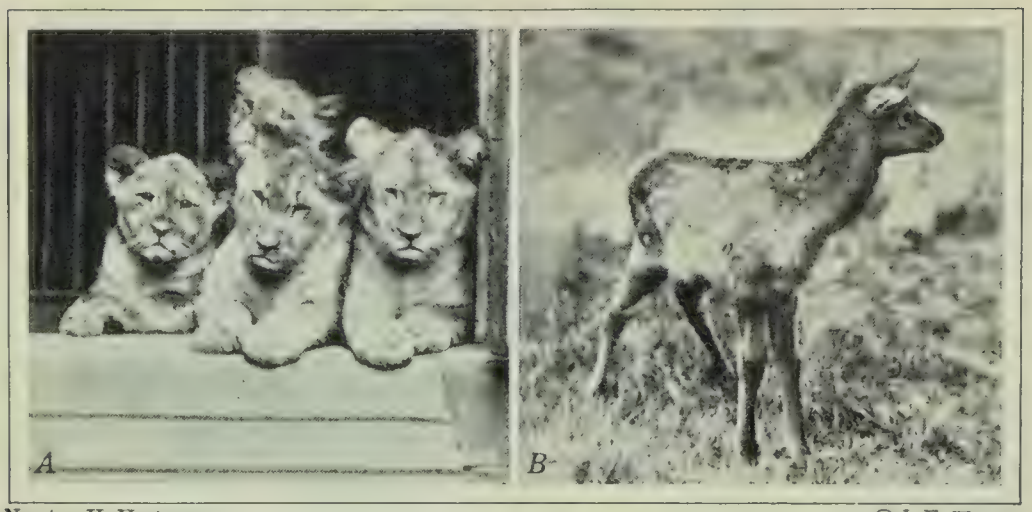


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FIG. 395. *A*, young lions in the Philadelphia zoo; *B*, elk calf, Yellowstone National Park. **Self-test on Scientific Principles:** "The higher animals care for their young until the latter are able to take care of themselves." How does this parental care increase the chances that these kinds of animals will continue to exist? How many ways can you state in which a parent animal, such as a bird or a dog, cares for its young?

mals (vertebrates) (Fig. 395), though some of the simpler plants and animals also have separate sexes and therefore reproduce sexually. In sexual reproduction an egg cell in the female organ is fertilized by a sperm cell from the male organ. The fertilized egg cell is an embryo. Before birth the embryos of the highest animals undergo considerable development within the bodies of the mothers.

Self-test on Problem XXXII–A. (*Do not write in the book.*) **1.** *Sexual* reproduction, or reproduction *with* sex, is the method of the simplest animals and plants.

2. The male cells develop in the *pistils* and the female cells in the *stamens* of flowers.

3. The food material stored in or around a plant seed nourishes the *young plant.*

4. Pollen is usually carried from one flower to another by either __(?)__ or the __(?)__.

5. *All* higher animals begin life as a single cell.

6. If a poplar twig is planted, a tree will sometimes develop from the twig. This furnishes an example of __(?)__ reproduction.

7. *Most* higher animals have two parents.

Problem XXXII–B · What are the Principles which Apply to Reproduction, and How can these be Applied in Improving Living Things?

Plants and animals reproduce rapidly. It is impossible to guess how many plants and animals there are in the world. There are many millions, for there are hundreds of thousands of different kinds. Moreover, plants and animals of kinds previously unknown are still frequently discovered, both on the land and in the water.

The number of plants or animals of any one kind would increase very rapidly if nothing prevented. Thus, a single dandelion or hollyhock plant will produce hundreds of seeds. Thirty-three years after the single Burbank potato plant was discovered, its descendants produced six million bushels of potatoes. If a pair of robins should live for five years and should produce two nests of young in each of the five years, if each nest of young should consist of two pairs which would begin nesting in their second year as their parents did, and if none died, there would be 6250 robins in this five-year family. The United States Department of Agriculture prints the statement that the descendants of a single pair of English sparrows, if not limited in any way, would in ten years number 275,716,983,689. A female lobster may lay from 5000 to 10,000 eggs in one season. A female black bass may lay thousands of eggs in her few hours of egg-laying. A Cecropia moth brought into the laboratory laid 126 eggs in one afternoon.

In general, the lower forms of life produce enormously greater numbers of offspring than the highest forms. It would not be long, however, if there were nothing to stop them, before the animals or plants of any one kind would be crowding each other all over the world.

Conditions limiting numbers. Fortunately every kind of living thing has its enemies, which prevent its multiplying too rapidly (Fig. 396). At almost every stage of life living things may become the food of other living things. Moreover, food supply, climate, and other conditions may keep animals and plants from

becoming too numerous. Those organisms which are best fitted to the environment survive and produce offspring. Those less well suited to the environment die.

FIG. 396. Self-test on Scientific Principles: "The limiting of numbers of organisms is due chiefly to the struggle for food." Explain this

Balance of life. It is true that if a new animal or plant is introduced into a region it may multiply rapidly for a time. But sooner or later it reaches the limit of the number of its kind that the new habitat will support. From that time on its numbers remain relatively unchanging. An example of these last statements is furnished by the English sparrow. In 1869 this bird was brought to the United States to help toward controlling caterpillars.[1] A statement printed in 1869 says: "John W. Bardsley of Germantown, Pennsylvania, who went to Europe several months ago, was commissioned by the city council to purchase 1000 English sparrows to be placed in the public squares of this city." The descendants of these thousand sparrows rapidly spread to all parts of the country. Now, however, their numbers are no longer increasing. The state of balance in the numbers of the various kinds of living things in a region is known as the balance of nature or balance of life (Fig. 397).

Variations in characters. The offspring of plants and animals are like their parents and also different from them. Thus, a litter of kittens will all resemble the mother and father cats in structure, form, and general appearance. Each kitten, however, will vary from both parents and from all the other kittens in some character, or characteristic. Even though they may all be of the same color, and apparently alike in every way, one will have thicker fur,

[1] *Caterpillar* (kat'er pil er): the wormlike young of moths and butterflies.

Portland, Oregon, Chamber of Commerce

FIG. 397. The annual "run" of smelt up the Sandy River, Oregon. **Self-test on Scientific Principles:** How do the facts shown here relate to the balance of life?

better eyesight, longer claws, sharper teeth, better digestion, or be better equipped with respect to some other character, than another.

Freaks and mutants. Offspring inherit their characters from their parents. The newly formed embryo plant or animal has within its microscopic body every character that it can ever have. Characters are passed on from generation to generation with the result that organisms of one generation usually are similar to their ancestors of many previous generations though never exactly like them. Usually the variations between parents and offspring are slight. Sometimes, however, they are not. Occasionally a plant or an animal appears with a character that had not appeared in its ancestors so far as known. For example, you have probably seen six-legged sheep, four-legged chickens, white crows, white goldfish, or similar unusual animals; and plants have appeared with blossoms or other structures unlike any others of their kind. Sometimes the offspring of these unusual individuals

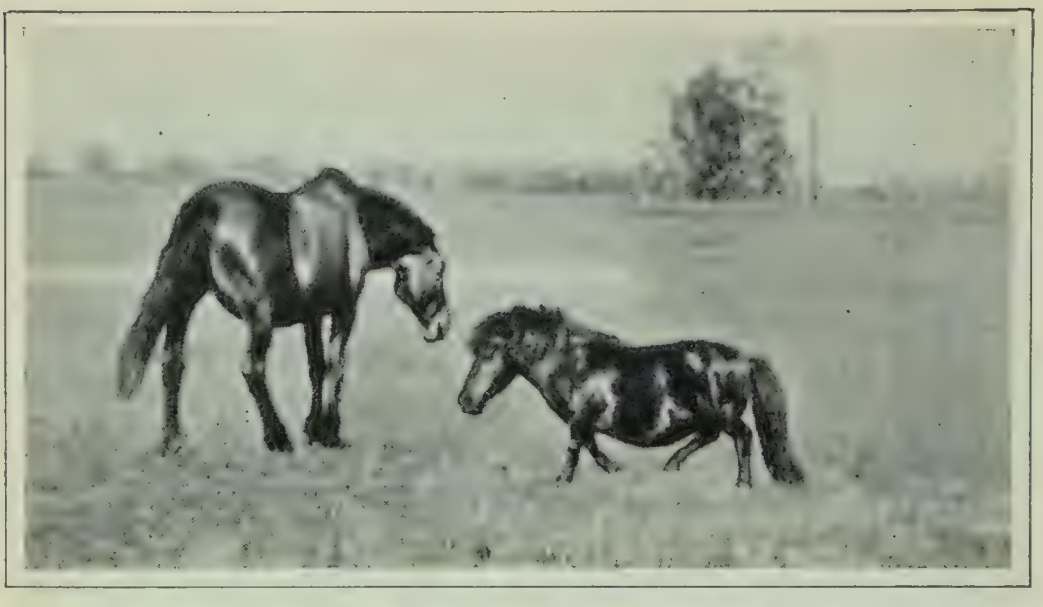

FIG. 398. A normal-sized horse and a short-legged pony. This short-legged pony had a colt which, like itself, had short legs. Would this indicate that the pony was therefore a freak or a mutant?

inherit the unusual quality, and sometimes they do not but are normal like their grandparents and earlier ancestors. If the unusual individual reproduces and has no descendants which possess the unusual character, that individual is known as a freak. But if the unusual character appears in the descendants, then the parent is known as a mutant (Fig. 398), and the unusual character is called a mutation. Thus freaks do not pass on their unusual characters, but mutants do transmit their unusual characters to succeeding generations. White rabbits are the descendants of a mutant white rabbit which was born in a litter of black, or brown, or gray rabbits. In certain communities there are many people who have six fingers or six toes, all of whom are descendants of one person, a mutant, who was born with one more finger or toe than his brothers or sisters.

Variations affect survival. Thus we see that organisms may change from age to age in two ways, (1) by the slight variations which occur in each generation and (2) by mutations. If the differences are such as to make it easier for the individual to survive than for others of its kind, the individual possessing these variations is likely to live to be old enough to have offspring which inherit the favorable character. If the inherited difference is

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FIG. 399. Albino, or white, Virginia deer, in the Philadelphia zoo. Do you think these mutant deer would have a better or a poorer chance to survive in the woods than the normal brown Virginia deer? Explain

such as to make it more difficult for the individual to survive, it is more likely to die or be killed and therefore fail to transmit the unfortunate character to following generations. These facts may be expressed in this scientific principle: "Those plants and animals which happen to possess the characters which best fit them to live successfully are the ones which are most likely to have offspring and to pass on their favorable characteristics to succeeding generations" (Fig. 399).

Laws of inheritance. Nearly a hundred years ago Mendel, an Austrian monk, as a result of many experiments with garden peas, discovered some of the important laws which govern heredity, or inheritance. He found that characters such as color, shortness, tallness, and the like breed true from generation to generation provided the parent plants were pure strains with respect to these characters. Thus, the flowers of a pure strain of tall peas when pollinated with the flowers from a pure strain of tall peas produced only tall peas. Pure strains having yellow seeds when bred with pure strains having yellow seeds produced plants having only yellow seeds. Mendel experimented further by crossing the various strains, as tall with short, smooth seeds with wrinkled seeds, white flowers with red flowers, and the like. The resulting

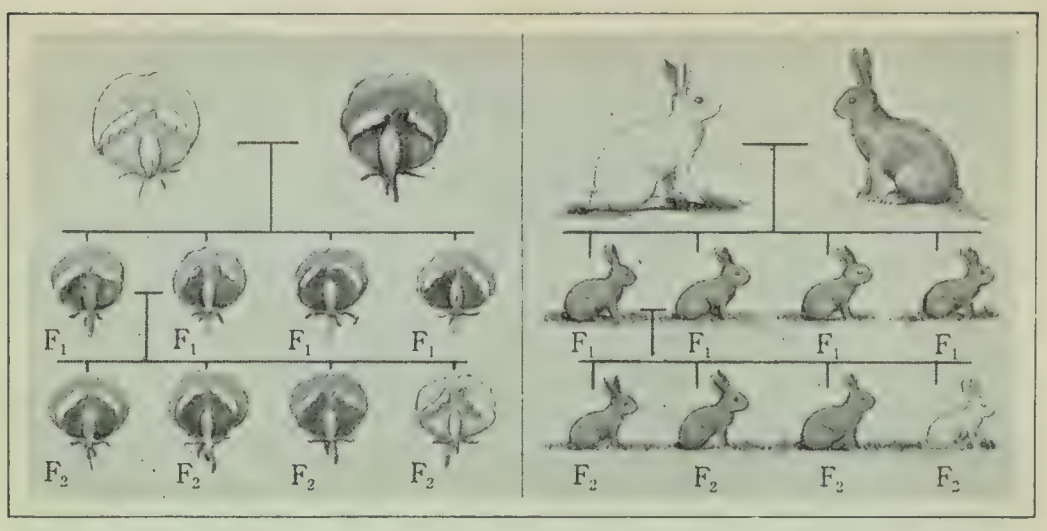


FIG. 400. Crossing white and colored sweet peas; and white and colored rabbits. Which trait is dominant and which recessive in each case?

plants were hybrids; that is, they were not pure strains. He found in every such case of crossing that one of the contrasting characters was stronger than the other. The stronger character was thus said to be dominant and the weaker character recessive. Therefore the hybrid offspring of pure short and pure tall peas were all tall peas, not medium-sized. In this case tallness was the dominant character and shortness the recessive character. When pure plants with yellow seeds were crossed with those having green seeds, the hybrid offspring all had yellow seeds. Thus yellow was dominant and green recessive as a seed color. When, however, Mendel bred the hybrid tall or yellow-seeded peas of the first generation with each other, he found that three fourths were tall and one fourth short or that three fourths had yellow and one fourth green seeds. Experimenting patiently with various other crosses with hybrids of different strains and of different generations, he worked out the proportions of offspring which would have the dominant and the recessive characters (Fig. 400). These laws of heredity which Mendel discovered have been proved to apply to all living things. Other scientists have discovered other laws of heredity since Mendel's time.

Applying the laws of heredity. The knowledge of the laws of heredity has formed the basis of all scientific plant and animal

breeding. There are many experiment stations where plants and animals are being studied in order that they may be improved both for man's uses and for his pleasures. Sometimes the improved individuals are produced by increasing slight variations of a desired kind of breeding and cross breeding through many generations. Sometimes the individual with the desired character appears as a mutant.

Probably the best known of the plant experimenters is Luther Burbank. He worked with enormous numbers of plants of the same kind. He studied them for desirable qualities, saving and breeding the most promising ones and destroying the rest. Sometimes he bred and destroyed many thousands of plants before he secured the one which possessed exactly the qualities he wished. He then made permanent the desired characters by applying the known laws of heredity. By these methods of making the most of slight chance variations, he produced the white (Lawton) blackberry, the spineless cactus, the Shasta daisy, and many other desirable plants. Using the same methods, other experimenters have bred cows which give enormously greater quantities of richer milk, hens each of which lays an egg almost every day, race horses of greater speed, new kinds of fruits, flowers, and animals. Other experimenters have produced from a single mutant such desirable plants and animals as beardless wheat, rust-resisting wheat, the Delicious apple, hornless cattle, short-legged sheep (Ancon), and many others. The methods of producing a pure strain either from a mutant or from organisms possessing slight variations, however, are the same. The individual with the desired character is crossed with other individuals, and its offspring are mated with each other until enough individuals possessing the character as a pure strain are produced to make the desired character permanent.

Can human strains be improved? The laws of inheritance apply to human beings just as they apply to all other living things. If people with superior qualities marry, their children will generally be superior (Fig. 401, *A*). If people having inferior qualities marry, their children are likely to inherit the undesirable qualities (Fig. 401, *C*). Furthermore, the least desirable characters sometimes are dominant over more desirable ones. Thus, in-

sanity is dominant over sanity, and tendencies toward certain diseases of the heart are dominant over strains not having this

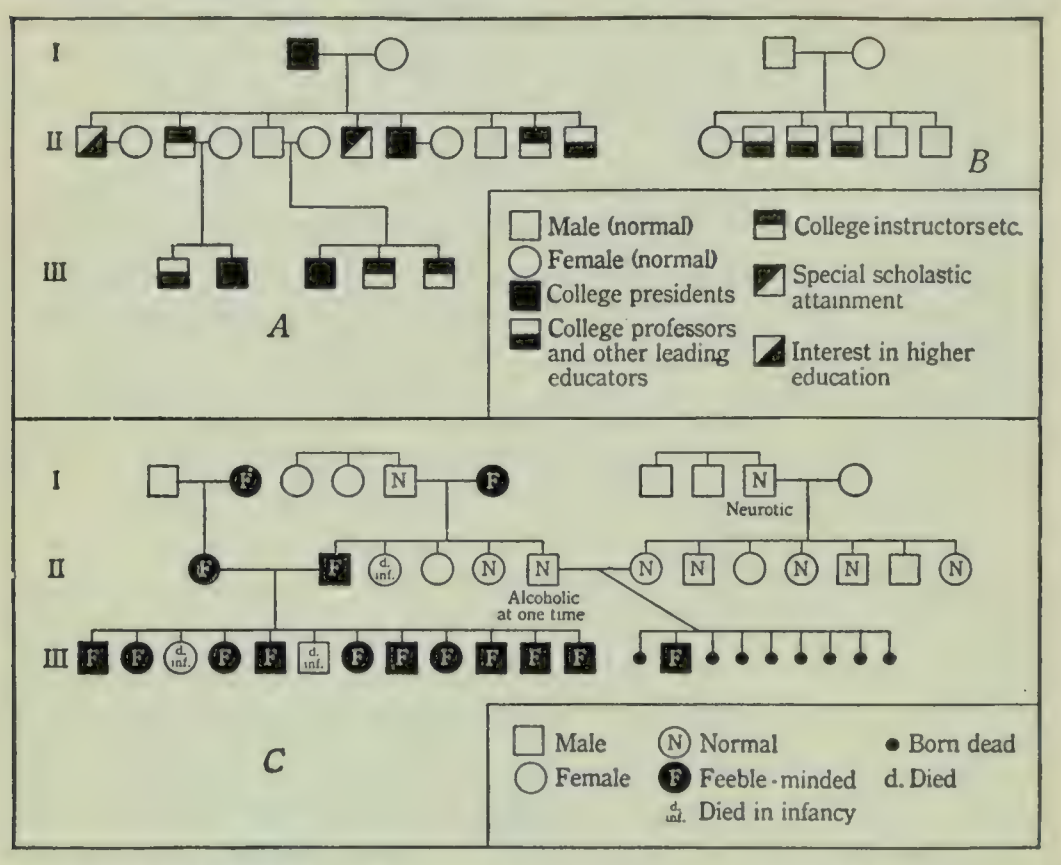


FIG. 401. *A* and *B*, the inheritance of desirable characters; *C*, the inheritance of undesirable characters. The man in the first generation in *A*, and both the man and the woman (cousins) in *B*, all had the same grandfather, a college president. About what proportion of the children of the second generation in *A* and *B* were superior? of the third generation in *A*? The histories of the men and the women represented by blank squares and circles in *C* are not known. About what proportion of the children of the third generation in *C* were feeble-minded? The two people of normal intelligence who married in the second generation were from inferior strains. Were their children inferior? (After Goddard)

tendency. Sometimes, also, an undesirable character which has not appeared in a family for several generations will appear in a child because the undesirable trait was all the while a part of the family heredity. Because of all these facts it is extremely necessary that people should study their own heredity and that of those whom they would like to marry, in order that undesirable characters may not be passed on to the children. Two examples will illustrate this point: Of the 480 members of the Kallikak

strain who have been traced to the same feeble-minded ancestor, only 46 were normal. Of the rest, 143 were feeble-minded, 71 were alcoholics, immoral, criminal, or otherwise defective, and 82 died in infancy. In contrast, of 1394 descendants of Jonathan Edwards, more than 360 were distinguished to a greater or a smaller degree, 295 others were college graduates, and not one was a pauper or a criminal.

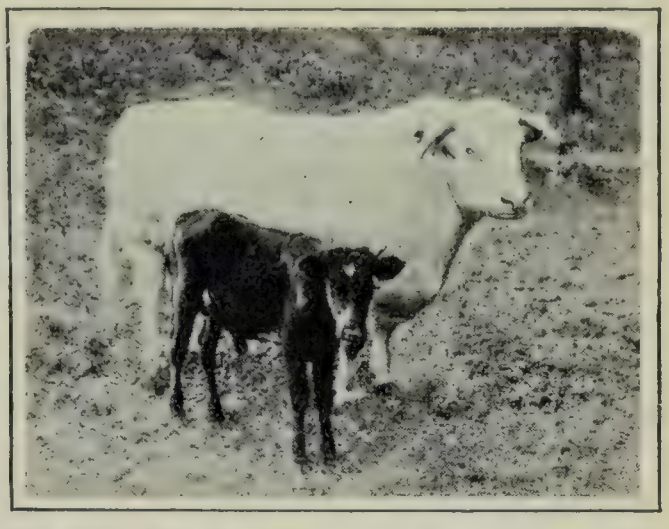


FIG. 402. These cattle are of the same age. The smaller one is of poor stock and has had poor food and care. The larger one is of good stock and has had abundant good food and the best care. Do you think the black one would have been as much superior to the white one as the white one now is to the black one if each had received the food and care given the other? Explain

Heredity, environment, and training. It is true that all that a plant, an animal, or a person *can* ever be is inherited. The heredity cannot be changed. Whether the best that is inherited is developed, however, depends upon environment and training. Proper care of plants and animals, and proper living by human beings, are necessary if the best qualities which their heredity makes possible are to be realized (Fig. 402). One who has inherited many good characters in body or ability can do much to make them of constantly increasing use.

Self-test on Problem XXXII–B. (*Do not write in the book.*) **1.** Most kinds of plants and animals produce *more* than enough offspring to maintain their numbers.

2. When the living things in a given region maintain about the same numbers of each kind, a _ _(?)_ _ has been established in that region.

3. The length of one's nose is an example of a *character*.

4. A cat with six toes on each hind foot bore a litter of kittens each of which had six toes on each hind foot. The mother cat was a *freak*.

5. In what two ways do organisms change from age to age?

6. The children of a brown-eyed parent and a blue-eyed parent would in general have brown eyes. *Blue* as an eye color is therefore dominant over *brown*.

7. Burbank produced most of his valuable new plants by selection of *mutations*.

8. One's abilities are due to *environment*; one's possibilities may or may not be realized because of one's *heredity*.

Self-test on Scientific Principles. 1. Can you explain and illustrate this principle: "All living things have enemies because of the struggle for food"?

2. Can you explain the relation of photosynthesis to the balance of life?

3. How would you explain to a boy or girl of your own age who had not studied science the principle stated on page 591?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Here is a problem for somebody who likes arithmetic or algebra. A pair of house wrens may produce two nests of young each year and may have as many as six or eight offspring in each nest. If one pair of wrens had begun nesting six years ago, and had had six young in each nest, if the young had begun nesting their second year, if all the offspring had been equally paired males and females, and if the first pair and all the offspring had lived until now, how many wrens would there be in this family at the present time? (For help in solving this problem look in your algebra textbook under the heading "Progression.")

2. Is education a part of one's heredity or of one's environment? Explain.

3. What relation is there between one's heredity and one's success in school or in life? Explain.

Exercises on Scientific Method. 1. **Inventing Hypotheses.** Many strange animals — for example, huge dinosaurs and mammals such as the saber-tooth tiger and the woolly elephant — once lived in various parts of the United States. How many hypotheses can you suggest to account for the fact that they have long been extinct, that is, that their kinds have entirely died out?

2. **Inventing Experiments.** Suppose you are raising white mice and find in a new litter one which is very different from the rest. How would you proceed to develop a new strain like this different individual? Consult a biology textbook if you are not sure of the steps to be followed.

Exercise on Scientific Attitudes. Below each of the following problems are five statements or comments. Which do you think a scientist would consider best? Support your choice by quoting one of the scientific attitudes (pp. 12 and 13).

The head of a prison noticed that every man in the prison serving sentence for stealing had flat and blunt fingers. He concluded that flat and blunt fingers always indicate a tendency to steal.

a. The warden's conclusion was absolutely sound.

b. His conclusion was unsound.

c. His conclusion might be sound but probably was not.

d. His conclusion was probably sound.

e. His conclusion was almost certain to be sound.

A dog-breeder recently reported in a radio broadcast that he owned a black and a white police dog, both of which had been born in the same litter of puppies. Three other puppies in the litter were of the usual color of police dogs.

a. Stranger statements than that have proved to be true.

b. The report is probably true.

c. When I *see* the white and the black police dogs, then I'll believe the report.

d. The report may be true.

e. Why shouldn't there be white or black police dogs?

Project. Make a study of special traits which have appeared in your family for several generations. Make heredity charts similar to those in Fig. 401, p. 594, showing the inheritance of these characters.

Special Reports. 1. How many examples of different ways in which plants reproduce can you find in your neighborhood?

2. Make a study of seed catalogues to find new varieties or improved varieties of plants. Find if you can whether they were developed from slight variations or from mutations.

Questions for Debate. 1. *Resolved,* That the government should pass and enforce more laws aiming to prevent immigration of people having undesirable characteristics and poor heredity.

2. *Resolved,* That more of our best types of plants and animals have resulted from breeding from mutants than from individuals having slight desirable variations.

3. *Resolved,* That environment has more to do with one's development than heredity.

Unit XIII · *The Nature and Needs of the Human Body*

PROBLEMS DISCUSSED IN THIS UNIT

For many people there is no more interesting subject for study in the whole field of science than the nature and care of the human body. Yet, through the centuries, this study has progressed slowly. In ancient Egypt it was a crime punished with death for anybody to remove for study any parts of a dead body. During the Middle Ages in Europe a barber was also a surgeon, and in England it was only about two centuries ago that the barber-surgeons were forbidden by law to perform any but minor operations, though they were still allowed to "draw blood" and to pull teeth. At the same time the surgeons who were not also barbers were forbidden to do "barbery and shaving." The "barber's pole" today carries white stripes to represent bandages and red stripes to represent blood.

To ancient and primitive peoples sickness has been a mystery. It was often thought to be a punishment inflicted by angry gods or angry spirits. Even in some highly civilized parts of this country, diseases are fought not with science but with charms and superstitious practices. Modern science, however, is making rapid progress not only in its knowledge and treatment of disease but in its knowledge of foods, as in every other subject dealing with the care and welfare of the body. The problems discussed in this unit are these:

What are the characteristics of the skeleton?
What are the structures and processes which are concerned with the use of energy in the body?
How is the human body equipped to act, to know, and to learn?
What are some important rules and safeguards of health?
What are the effects of the use of alcohol and tobacco?
How does science fight disease?
How may we solve some of the problems in relation to foods?

Chapter XXXIII · The Human Machine

Questions this Chapter Answers

What kinds of supporting structures do animals have?

What are the important structures which make up the human skeleton, and what are the functions of these structures?

What structures are concerned with the circulation of the blood, and how do these structures function?

What structures and processes are concerned with the preparation of the various classes of foods for the body's use?

What structures are concerned with respiration, and how do these function?

What structures enable us to act, to know, and to learn?

How may health be improved?

What are some important rules to follow in case of accident?

Problem XXXIII–A · What are the Characteristics of the Skeleton?

Supporting and protecting structures. The Protozoa (see Glossary) have soft bodies with nothing whatever resembling bones. Some, however, have shell-like coverings, and a few cover themselves with an armor of microscopic pebbles. Most plants have woody tissues which support their bodies in somewhat the same way as do the skeletons of higher animals. Many of the simpler plants and animals which live in water have soft bodies and need no supporting structures, because the water holds them up. Animals such as oysters and clams have shells which protect their soft bodies. Still higher animals, such as insects and crabs, have skeletons on the outsides of their bodies which serve both for protection and for support. No animal simpler than the fishes has a skeleton within its body. Only the fishes, amphibians, reptiles, birds, and mammals have true bones. The skeletons of the higher animals, such as the dog, the cat, the elephant, the horse, and man, are very similar in structure and in the number and arrangement of their bones.

***The human skeleton.** The human skeleton (Fig. 403) consists of from two hundred four to two hundred eight bones, depending on whether some of the smaller ones grow together. The joints at the wrist, elbow, shoulder, hip, knee, and ankle permit ready movement. The backbone, or spine, has a joint between each pair of bones, which makes possible bending and twisting the neck and back. Where movement in only a few directions is needed, as in the arms and legs, the bones can be relatively long. Where great flexibility[1] is required, however, as in the hands and feet, the bones must be numerous and small.

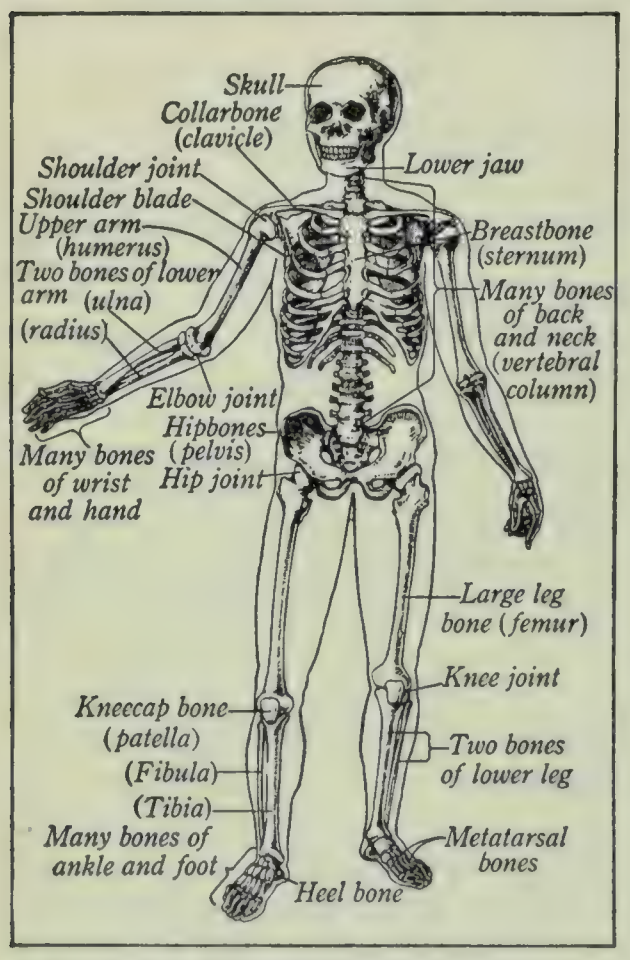


FIG. 403. The human skeleton. How many examples of the different types of joints can you locate?

The skeleton gives support to the various tissues and organs of the body. It also serves as the solid but movable framework on the separate parts of which the muscles do their work.

Bones and joints. *Experiment 103.* How do certain bones move? Sitting at a table, place your hands with the backs upward on the table. Have the elbows also resting on the table. Without raising the elbows from the table see if you can turn your hands over so that the backs are on the table. Can you locate the bones and joints that make this movement possible? Standing straight up (that is, erect), see if you can put first one hand and then the other behind you and with its back between your shoulders. What bones and joints make this movement possible?

[1] *Flexible* (flex'i bl): able to bend readily without breaking. *Flexibility* (flex i bil'i ty): the quality of being flexible.

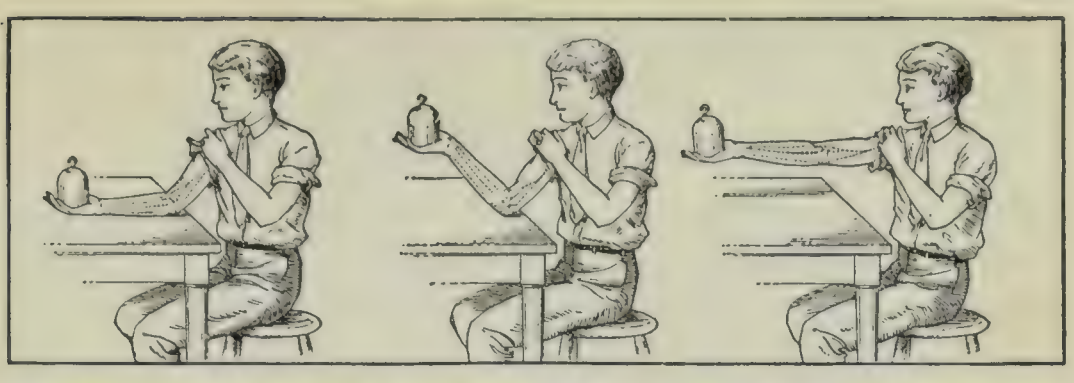


FIG. 404. Note that the arm is a lever of the same type as the fishing pole (Fig. 94, *B*, p. 146) : the elbow is the fulcrum, the weight is the resistance, and the muscle applies the force. One muscle pulls the arm up and another straightens it out. Can you tell which muscle in each case?

Experiment 104. How much movement is possible for the jaws? Can you move your upper jaw? Can you move your lower jawbone upward and downward, backward and forward, and sidewise? What bones and joints make this movement possible?

*If we study carefully the structure of the joints at the hip and shoulder, at the elbow and knee, and at the waist, it becomes clear that they are not alike. The elbow and knee joints move back and forward only, like the hinges of a door. These are called hinge joints. The shoulder and hip joints are made so that the ball-shaped end of one bone fits into a hollow place, or socket, of the other bone. This is called a ball-and-socket joint. Such a joint permits motion in many directions. The joints at the wrists and ankles are sliding joints.

*The bones of the face and skull, except the lower jawbone and the bones within the ear, are fastened together by joints which have very little or no movement. The edges of the skull bones fit into one another as the teeth of two saws might fit together. Such a joint is called a suture. In children these joints may allow a little movement, but in older people no movement in them is possible. In fact, babies do not have all the bones joined at the tops of their heads until they are one or two years old.

Muscles make the body move. *Experiment 105.* How do the arm muscles act when the hand picks up a weight? Place the arm flat on the table as shown in Fig. 404. Lift a weight as shown in the

figure and, by watching the action of the muscles of your arm, see if all the actions shown in the figure can be traced in your own arm and hand. In this experiment it is possible also to note the changes in the muscles as the hand moves. What are these changes?

*All over the body are muscles, — some long and slender, some drawn to a point at each end, and some flat and thin. These muscles are attached to the bones by tendons at their ends. The bones and tendons act as levers lifting or otherwise moving the various parts of the body. Only a detailed study of their anatomy[1] could give us more than general information about the muscles. The muscles, together with fatty[2] tissues, cover the skeleton of the body, and over all this is the skin. These structures together give the body its form.

Self-test on Problem XXXIII–A. (*Do not write in the book.*) **1.** Only the *higher* animals have bones inside their bodies.

2. If it were not for joints, free movement of the parts of the body would be *difficult.*

3. Give at least one example of each type of joint.

4. The parts of the body are moved by the action of __(?)__.

Problem XXXIII–B · What are the Structures and Processes which are Concerned with the Use of Energy in the Body?

The most important pump in the world. A little over three hundred years ago William Harvey, an Englishman, announced his discovery that the blood circulates through the body and is kept moving by the heart. This announcement was received with laughter, and it was long before the facts of the circulation of blood were generally accepted.

Experiment 106. How can you tell how often your heart pumps, or beats, and how can you change its rate of beating? By placing the first finger of one hand across the wrist of the other hand, or by placing a first finger tightly against the neck just back of the lower jawbone, you can feel the pulse or flow of the blood as it is sent from the heart.

[1] *Anatomy* (an at'o my): the study of details of structures of plants and animals.

[2] *Fatty* (fat'ty): composed of fat.

Count the number of heartbeats, or pulsations, in one minute. Make a record of the pulses of five of the pupils. Then have these pupils run or walk rapidly round a block or a similar distance elsewhere and return to the classroom. Take their pulses again and make a record of these. What differences can you observe in the pulsations? How can you explain these differences?

The blood. The blood contains millions of disk-shaped bodies called red corpuscles and a smaller number of irregular bodies called white corpuscles. The red corpuscles carry oxygen from the lungs to the cells and carbon dioxide from the cells back to the lungs. The white corpuscles are able to destroy disease germs in the blood and the body tissues. The liquid part of the blood, the plasma, carries food and special substances (called hormones) manufactured by the glands[1] to the muscles and all other body cells. The plasma also carries wastes of various sorts from the cells to the liver, the kidneys, and the skin.

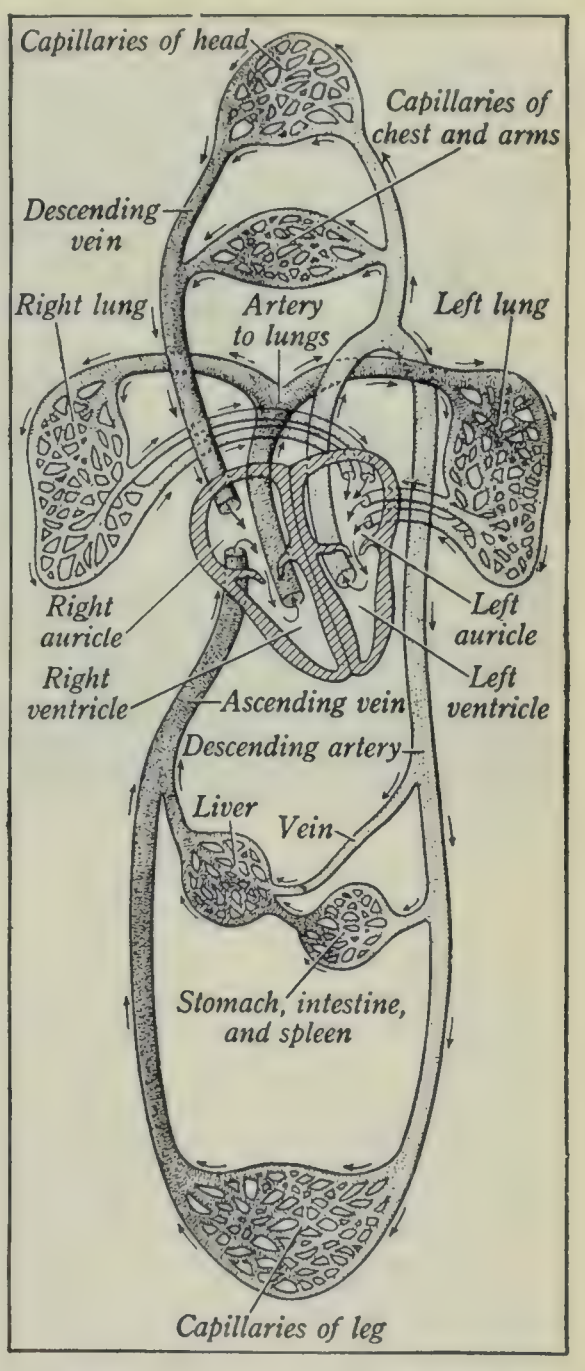
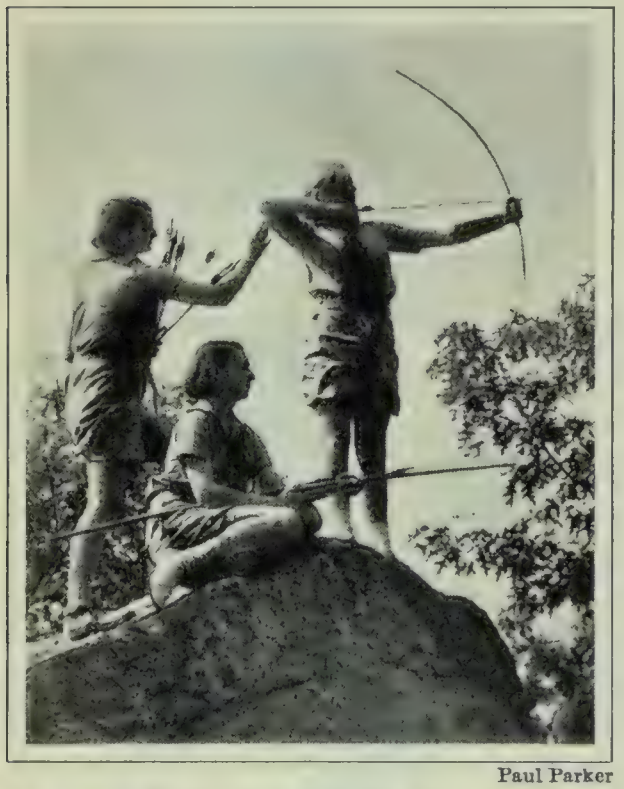


FIG. 405. Can you trace the flow of the blood from the right auricle of the heart through the head or the legs and back to the right auricle?

How the blood reaches every cell. The blood is pumped from the heart into large heavy-walled tubes called arteries (Fig. 405). The arteries

[1] *Gland:* an organ for making a special kind of body fluid.

divide and become smaller as they reach distant parts of the body. Finally the blood leaves the smallest arteries and goes into tiny hairlike tubes called capillaries. These capillaries, into which the blood goes, form a network.[1] They are in close contact with all the living cells, so that as the blood flows through them it is in contact with the living cells. The capillaries enlarge into small tubes much like small arteries, but they do not have heavy walls. These are called veins. Smaller veins join to form larger ones, and finally large veins lead back to the heart. The blood makes this round from the right side of the heart to the lungs, from the lungs back to the left side of the heart, thence through arteries and capillaries to all parts of the body; then from the capillaries into veins, and through these back finally to the right side of the heart (Fig. 405). The arteries, capillaries, and veins are known as blood vessels.



Paul Parker

FIG. 406. Exercise in the open air promotes a healthy circulation. Why?

Bruises. When a part of the body is bruised, the capillaries, or even the veins and arteries, may be broken. In such cases blood passes out of the blood vessels and lodges among the tissues of the body, producing the blue or black place called a bruise. If the blood vessels heal quickly, the escaped blood may be absorbed and carried away and the dark spot will disappear. When more serious bruises occur, the damaged tissue is slowly replaced by new blood vessels and tissues.

[1] *Network* (net'work): a mass of threads running in all directions as in a net.

***Bleeding from wounds.** When capillaries or small veins are cut, the blood flows slowly. But if an artery is cut, the pulsations of the heart cause the blood to flow more rapidly. There is more danger from the loss of blood from cut arteries than from cut veins and capillaries. Arteries are, however, not so near the surface as veins and thus are less easily injured.

FIG. 407. Vigorous outdoor exercise promotes good appetites. Why?

Clotting of blood. When the blood is exposed to the air, it coagulates,[1] or clots; that is, its solid parts join together and separate from the liquid part, or serum (see Glossary). Hence the clotting of the blood closes the wound and stops the bleeding. Some bleeding from wounds is desirable, since the flow of blood carries out disease germs. Too great loss of blood, however, may cause serious harm and even death.

Keeping up the body's supply of energy. Energy in the form of food must be fed into the muscles through the capillaries from the blood (Fig. 407). The heart does not supply energy to the blood; in fact, the heart itself gets tired. Its muscles lose the ability to keep working unless the living cells of the heart's muscles, as is true of all other living cells, get new supplies of energy from the capillary blood supply.

Digestion in the mouth. The digestive system prepares food for use in the body. Digestion begins in the mouth. The teeth break and crush the food. The mouth has special organs, called

[1] *Coagulate* (ko ag'u late): to become like a jelly or half-solid substance. *Coagulation* (ko ag u la'shun): act of coagulating, or clotting.

glands, which produce a digestive enzyme (see Glossary) called saliva. Saliva acts upon the starch in such foods as bread and potatoes, changing it to sugar, which can later be absorbed into the blood. Thorough chewing permits more of the starch to be digested by the saliva. It used to be thought that the drinking of water while eating interferes with the action of saliva, but this seems unproved.

***Digestion in the stomach.** From the mouth the food goes to the stomach through the tube called the esophagus. In the stomach the digestion of proteins and fats and of milk is begun by the gastric juice. This is produced by glands in the walls of the stomach. Gastric juice is composed of weak hydrochloric acid and three enzymes. Three layers of muscles in the stomach walls, acting in different directions, produce a regular motion which turns and mixes the food, thus helping to make it into liquid form.

Digestion in the small intestine. From the stomach the partly digested food passes into the small intestine. Here digestion of proteins, fats, and starch is completed by enzymes from the pancreas (see Glossary) and from glands in the walls of the small intestine. Also bile, added here from the liver, assists digestion without actually helping to digest the food as do the enzymes.

How food reaches the cells. In the linings of the small intestine there are folds of tissue covered with millions of tiny finger-like structures (villi). In the walls of these structures are millions of capillaries. Food is absorbed into these capillaries. Any material that cannot be absorbed passes into the large intestine, where unused food and waste matter gather till they are expelled from the body.

From the capillaries of the small intestine the digested food is carried by the blood to capillaries in every part of the body. Food energy needed by living protoplasm is absorbed by every cell from the blood in the capillaries.

Hygiene of the digestive system. We might laugh at the man who crowded his furnace with so much coal that the fire was choked from lack of air. Yet it is quite as ridiculous for one to crowd into one's stomach such an amount of food as to prevent proper digestion of any of it. Overeating produces a strain on

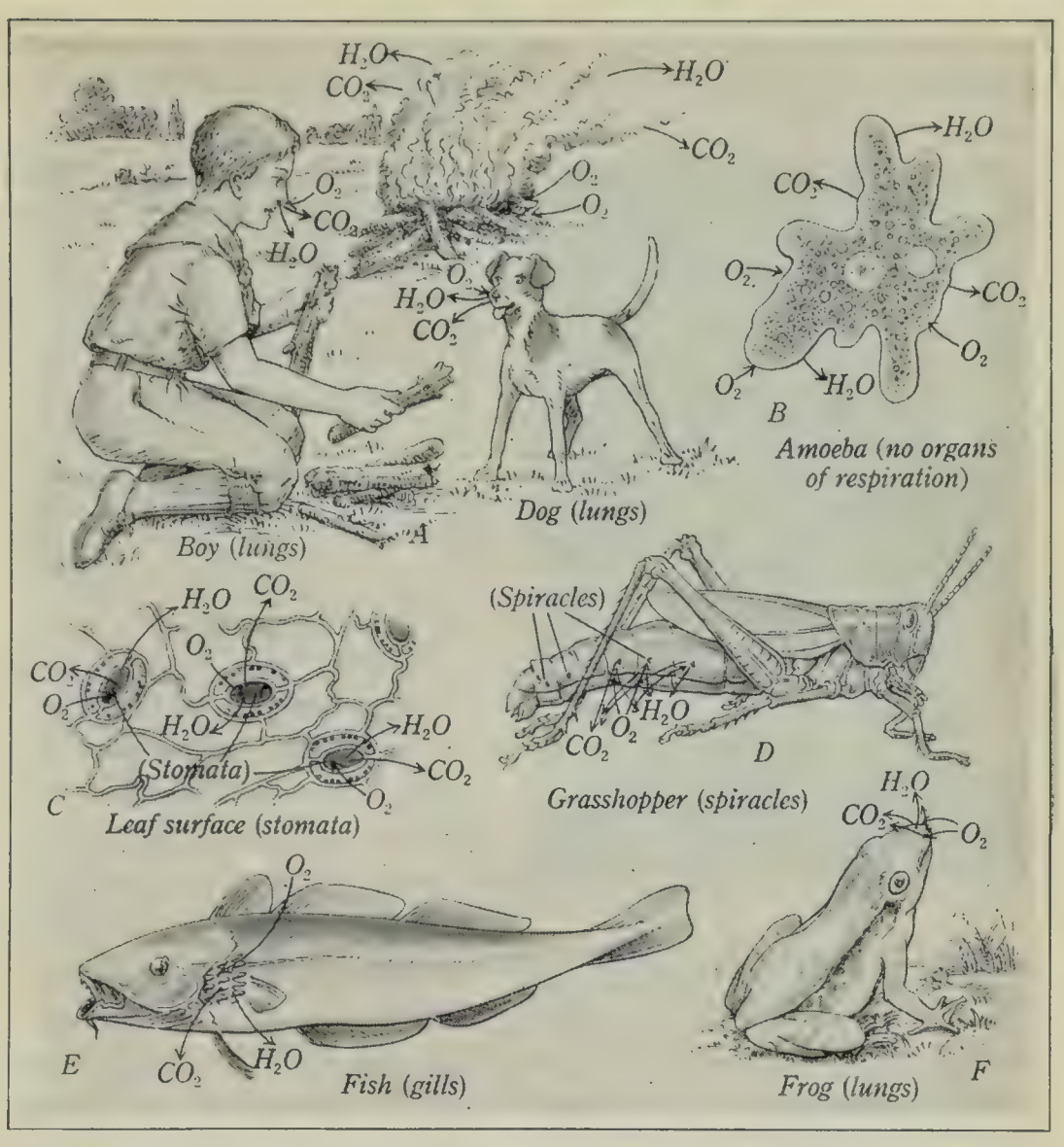


FIG. 408. **Self-test on Scientific Principles:** How do these drawings illustrate the principle "Whenever fuel is burned, the energy of the fuel is changed to heat energy and usually also to other forms of energy, and carbon dioxide (CO_2) and water (H_2O) are given off as waste products"? (O_2 is the chemical symbol for oxygen)

the digestive organs, the heart, and other organs and may result in undesired fat.

***Breathing and respiration.** Breathing refers to the act of taking air into the lungs and sending it out through the nose and mouth. Respiration includes breathing, and it also includes the passage of oxygen into the cells and of carbon dioxide and water out of them. Only the higher animals breathe, because only the

higher animals — the reptiles, the amphibians, the birds, and the mammals — have lungs. But respiration is necessary to every living thing (Fig. 408).

Acme

Fig. 409. These girls were selected from all the girl students of a great Chicago high school as having the best posture. They are here illustrating the kinds of exercises which help one to have good posture. How many reasons for cultivating good posture can you give?

It was formerly thought that people should practice deep breathing in order to form the habit of breathing as deeply as possible. It is now believed that such practice may result in more harm than benefit. If one has good posture (Fig. 409), he will breathe as deeply as is necessary for good health.

In breathing, oxygen passes through the walls of millions of capillaries in the lungs and combines with the hemoglobin, which is the coloring material of the red corpuscles. The oxygen is carried by the blood from the lungs first to the heart. It then passes to all parts of the body, where it oxidizes some of the protoplasm of every cell, releasing the energy of the protoplasm. Part of this energy is heat.

Getting rid of wastes (excretion). The waste products which result from respiration consist chiefly of water, carbon dioxide, and compounds of nitrogen, phosphorus, and sulfur. The blood carries the carbon dioxide to the lungs, where it passes along with water vapor through the walls of the capillaries and is breathed out. The compounds of nitrogen, phosphorus, and sulfur are removed from the blood chiefly by the kidneys and pass out of the body with the urine. Other waste products are removed by the liver. If waste products were not removed, they would poison the body.

The skin functions in removing some wastes from the body. Sweat, that is, water containing certain waste products, passes from the blood to the surface of the skin, where it evaporates, leaving the wastes. Regular bathing removes these wastes and helps to keep the skin in condition to do its work.

Self-test on Problem XXXIII–B. (*Do not write in the book.*) **1.** The *white* corpuscles of the blood carry oxygen to all the cells and carbon dioxide from them.

2. The blood is caused to circulate through the body by the action of the *muscles.*

3. Trace the circulation of the blood from the little finger to the heart and back to the little finger.

4. When blood flows *rapidly* in pulses from a wound, it is a sign that a *vein* has been cut.

5. *Most* wounds should be allowed to bleed a little.

6. Digestion is begun in the _ _(?)_ _, is continued in the _ _(?)_ _, and is completed in the _ _(?)_ _.

7. Digested food passes into the blood through the walls of the *stomach.*

8. Most living things must take in *nitrogen* and give off carbon dioxide.

9. Food energy is transformed into heat and other forms of energy in *most* of the living cells of the body.

Problem XXXIII–C · How is the Human Body Equipped to Act, to Know, and to Learn?

How we know and do the things that we know and do. All through the body there are threadlike cells called nerve cells, or nerves (Fig. 410). By means of these we find out all we know about what occurs in our bodies and about the world outside ourselves. Without these no learning and no activities or processes of the body would be possible. The nerves, or nerve fibers, connect directly with the nerve centers in various parts of the body. These are masses composed of many nerves. They control all the movements and activities of the body. The largest nerve center is in the skull and is called the brain. Other large nerve centers are at the base of the brain, in the hollows of the vertebrae of the

back, and at many other points in the body. All the nerve centers are connected by nerves. As a result there is a complete system of nerves extending to every part of the body.

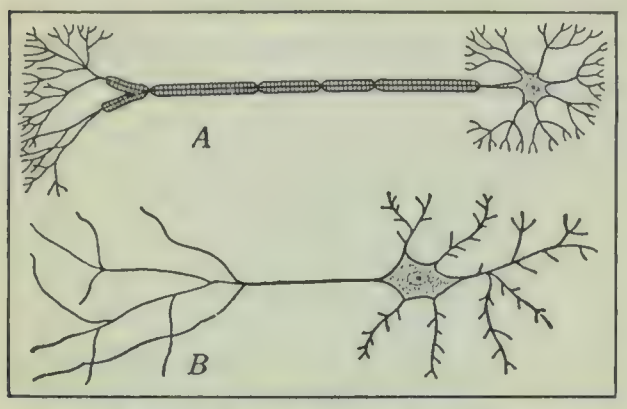


FIG. 410. Exercise on Scientific Method (Making Inferences): How many reasons can you give which indicate that there are different kinds of nerves in the body?

Most of the nerves extending farthest from the main nerve centers end in such parts as the muscles, the skin, and the digestive system. Some nerves, however, run to special parts of the body for doing special kinds of work. The ends of the nerves in the fingers and elsewhere give to us the sense of touch. Certain nerves in the eye, the ear, the nose, and the tongue make up the special sense organs. Nerves of one type carry impressions of every sort from all parts of the body to the brain and the other nerve centers. Nerves of another type carry from the nerve centers to the muscles "orders" for all movements which the body makes.

The proper care of the special sense organs. Everyone should take the best possible care of his eyes, his ears, and his other special sense organs. He should also have plenty of sleep, especially while he is growing, in order that his nervous system may continue to do its work well. Sleep and nourishment enable the body to clear out its wastes and to gain new energy.

The special study of the organs of the body and how they work is called human physiology. The special study of the proper care of the body to keep it always in good health is called hygiene. The special study of how we use the nervous system in thinking and acting is called psychology.

Why we act as we do. There are certain acts which we can perform only by putting all our attention upon them. Such acts include studying, repairing a bicycle, making a dress or a machine. These are called voluntary acts. There are other acts which we perform without thinking about them. For example, we quickly

pull the hand away when it touches something hot, or we cough when we get something in the windpipe. Such actions are called reflex acts, or reflexes. There are still other acts, such as eating, which are quite complex but which we can perform successfully the first time we attempt them. Such acts are called instincts or instinctive actions. There are yet other actions which we now do without thought but which had to be learned with careful attention during the learning. Such actions include walking, catching a ball, driving a car, and the like. Such actions are habits. Reflexes, instincts, and habits are all performed without conscious thought and are therefore called involuntary acts (Fig. 411).

FIG. 411. A mother bird feeding her young. What instinct is shown here?

Control of voluntary and involuntary acts. Voluntary acts are controlled by the highest nerve center, the brain. Involuntary acts are controlled by lower nerve centers. Of the involuntary actions, only the habits can be formed or readily changed. It is important, therefore, to form as many good habits as possible so that the body may work well while the brain is free to attend to the necessary voluntary acts.

Self-test on Problem XXXIII–C. (*Do not write in the book.*) **1.** The body cells which have to do with learning and with causing the muscles to move are __(?)__.

2. Deciding to study your lesson is *an involuntary* act.

3. Dodging a stone thrown at one is an example of __(?)__.

4. Building a nest is an example of __(?)__.

5. Learning how to study effectively is a __(?)__.

6. All actions requiring thought are controlled by the *lower nerve* centers.

Problem XXXIII–D · What are Some Important Rules and Safeguards of Health?

***First aid.** In case of accident, the first necessary action is to get the injured person out of further danger. The second is to call a physician. In moving a person who has a broken bone, great care must be taken not to bend or twist the body into unnatural positions. The injured person may usually be safely carried on a blanket or a wide board. Never permit a person who has been badly injured in an automobile accident to stand or walk. Always carry him from the car to the place where a physician may examine him.

Treatment of burns. Long ago the Chinese discovered that the pain of burns could be soothed by applying a strong brew of tea. The modern tannic-acid treatment of burns which many physicians approve is an application of this same discovery. Four to eight teaspoonfuls of tannic-acid powder are dissolved in a tumbler of water. Clean cloths previously made sterile, that is, free from living germs, by boiling, are placed over the burned area and are kept soaked in the tannic-acid solution until the burned skin turns a rich brown. The tannic-acid solution must always be made up fresh at the time of the accident. If no tannic-acid powder is available, a strong brew of tea, made fresh and cooled, has enough tannic acid in it to serve.

In the case of a serious burn, even though first aid seems to be successful, it is always best to consult a physician.

***First aid in cases of gas poisoning and drowning.** Gas poisoning most often results from escaping coal gas or cooking gas and from carbon monoxide gas. In gas poisoning the carbon monoxide combines permanently with the hemoglobin of the blood and thus prevents the blood from carrying oxygen. The first thing to do in a case of gas poisoning is to get the person into fresh air. The next is to call a physician. Start artificial respiration as described in the next paragraph.

*Drowning also requires very prompt action. Artificial respiration should be started as soon as possible. Figure 412, *A*, shows how to handle the patient so as to clear the upper air passages of

Ewing Galloway

FIG. 412. The stages of artificial respiration. **Special Report:** The use of oxygen in cases needing artificial respiration. (Consult your physician or the local fire department)

water. Then place the patient as shown in *B*, and place your hands as shown in the figure. Then with your own body in the position shown in *C*, and with your weight partly thrown upon your hands, force the air out of the patient's lungs. Immediately take the position shown in *D*, and wait two seconds for the patient's lungs to fill with air. Then repeat these operations until natural breathing is started. Do not give up until you have continued the artificial respiration for four hours.

When the patient revives, keep him lying *on his face* until breathing is easy and normal. Do not turn him over on his back. When he is out of danger he will turn over of his own accord.

Treatment of cuts. *Wet bandages.* The most common accidents are cuts. If no glass or dirt is left in the wound, it may be treated at once. A soft-cloth bandage saturated with a dilute salt solution is best. Use one teaspoonful of salt to a pint of water. The wet dressing maintains drainage from the wound and thus helps to remove any poisons which may be formed.

Assisting coagulation. When an artery is cut, the pulses of the heart may keep the blood from coagulating in the wound. In such a case a cloth or a cord tied tightly near the cut and on the side nearest to the heart may stop or reduce the flow of blood and permit it to coagulate in the wound. There is danger, however, if the circulation of blood is shut off by the cord for longer than ten or fifteen minutes. If serious bleeding occurs as the result of cutting a vein, the cloth or cord should be placed on the side of the wound farther from the heart. After a wound is safely closed, good circulation in the tissues about it is essential to the process of replacement and recovery.

**Use of antiseptics.* The bacteria which produce lockjaw, or tetanus, get into the body by way of cuts, tears, pricks, and scratches. Those which produce infections that may develop into blood-poisoning are introduced in the same way. Therefore it is of the greatest importance that there shall be thorough and prompt treatment of such wounds by use of a disinfectant or an antiseptic (see Glossary). Merthiolate is an excellent household antiseptic.

Treatment of infected wounds. If a wound has become infected or has foreign substances in it, washing it thoroughly with a salt solution is helpful. A wound should be kept clean and bandaged with sterilized[1] cloth until the injured tissue has been replaced. In healthy people such wounds will quickly heal when no infection has been allowed to get started. Nearly all cases of serious difficulty from cuts are due to neglect during the first day or two.

Patent medicines. The use of patent medicines should be avoided. The fact that a remedy may be widely advertised over the radio or in the newspapers and magazines is no evidence that it possesses any value whatever. Many patent medicines are actually harmful, and a few have been known to cause death. In most cases they are harmless but worthless. One of the chief dangers from using them is that the sufferer usually delays consulting a physician until it may be too late.

Nobody would be so absurd as to believe that all people having foot trouble should wear the same kind of shoes or that all people having eye trouble should wear the same kind of glasses. It is

[1] *Sterilize* (ster'i lize): to destroy all germs in or upon a substance.

just as absurd to expect the same medicine to cure the ills of everybody having the same signs of disease, because different diseases often produce similar signs.

Ewing Galloway

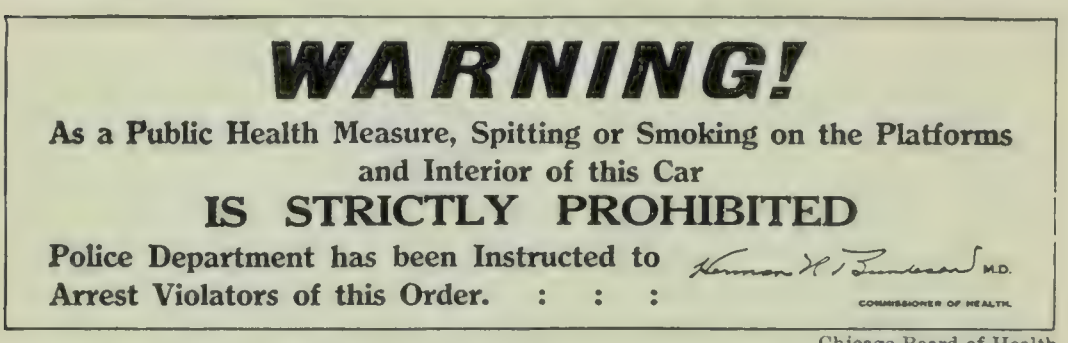
FIG. 413. How many benefits from recreation and play out of doors can you name?

*Individual health. Whether most people keep well is largely a matter of their own choice. People may bring on ill health through (1) the loss of sleep, (2) eating too much, (3) worry, (4) too long-continued work without stopping for rest and recreation, (5) too much excitement, or (6) the use of alcohol. On the other hand, vigorous health is almost certain to follow if these rules are observed: (1) eat only good food in proper amounts; (2) keep cheerful and avoid worry; (3) breathe plenty of fresh air and see that the ventilation of your home is good; (4) take regular exercise (Fig. 413); (5) get plenty of sleep; (6) follow any special practices which you have already proved to be good for yourself.

Community health. With proper care the spread of common diseases may be reduced. In a school in which accurate records were kept for ten years it was possible to show that school time can be saved when proper attention is given to health. Of course pupils sometimes remain away from school when not ill, and sometimes they come to school when ill and in danger of giving diseases to others. In this school those who were ill with infectious[1] diseases were not allowed to attend, but at the same time an effort was

[1] *Infect* (in fekt′): to transfer harmful germs to wounds or to well people. This occurs when well people touch objects that have germs upon their surfaces or when well people touch other people whose clothing or bodies carry the germs. *Infection* (in fek′shun): the act of infecting or the condition of being infected. *Infectious* (in fek′shus): able to be transferred by infection.

made to convince the students that they should attend except when ill. In 1917–1918, as a result of these policies, 14.9 per cent


WARNING!
As a Public Health Measure, Spitting or Smoking on the Platforms and Interior of this Car
IS STRICTLY PROHIBITED
Police Department has been Instructed to Arrest Violators of this Order. : : :
M.D.
COMMISSIONER OF HEALTH

Chicago Board of Health

FIG. 414. A poster in a streetcar. Why are such measures as this necessary?

of the school days were lost by absence; in 1922–1923 the loss was 8.17 per cent; and in 1927–1928 the loss was 8 per cent.

*The growth of bacteria can be prevented by use of disinfectants or by germicides. Formalin, carbolic acid, chlorine solutions, and bichloride of mercury in small quantities will act as germicides. These substances, however, should be handled only by those who understand their action. In strong solutions they are all poisons. Only very dilute solutions are safe to keep in the home, and even then care should be taken to avoid their improper use, and especially to keep them where young children cannot reach them.

*To care for the health of the community and to prevent the spread of disease, we have laws (1) for the disposal of household sewage and garbage, (2) to prevent unsanitary practices (Fig. 414), (3) for disposal of city sewage and garbage, (4) for disinfecting houses where there have been infectious diseases, (5) for quarantining persons or regions that have infectious disease, (6) for regulating milk, water, and other food supplies, (7) for reports on cases of sickness and death, — in fact, laws made to provide and to keep proper conditions for good health for all. There are local, state, and national officers and organizations whose business it is to know the laws and to see that they are enforced. It is the duty of every good citizen to help in every way to enforce these laws.

Self-test on Problem XXXIII–D. (*Do not write in the book.*) **1.** The chief danger from open wounds is from *germs* which get into them.

2. *Most* small wounds should be sterilized with an antiseptic.

3. In cases of gas poisoning or drowning, the artificial respiration should be continued for at least *fifteen minutes.*

4. Reliable information concerning patent medicines can be secured from _ _(?)_ _ in the city of _ _(?)_ _.

5. Highly advertised medicines are *very* likely to be effective in curing diseases.

Problem XXXIII–E · What are the Effects of the Use of Alcohol and Tobacco?

Alcohol and its effects. ***Experiment 107.*** What are some of the effects of alcohol? In a beaker place a piece of lean meat and cover it with alcohol. After an hour examine the meat to see if it has changed in any way. Put part of the white of an egg into each of two small beakers and part of the yolk into each of two other beakers. Pour a little alcohol into one of the beakers with the egg white and into one with the yolk, and pour water into each of the other two beakers. What changes, if any, appear in the meat or the egg?

Place one animal in each of a pair of cages and keep them without food or water until they are hungry and thirsty. Then water and feed one with fresh water and food. Water the other animal with a 10 per cent alcohol solution and feed it with vegetables which have been covered with alcohol for an hour. Observe the two animals to determine any differences in their feeding or drinking or in the results afterwards. Do not continue this experiment longer than is necessary to make your observations. Did the animal used in your experiment eat food or drink water which contained alcohol? If so, could you observe any effect upon it? Did the animal seem to be helped by the alcohol?

Self-test on scientific method (*recognizing defects in experiments*). Something necessary has purposely been omitted from the directions for this experiment. Can you discover what it is?

Proper uses of alcohol. Alcohol has important uses in science, industry, and the arts. It may sometimes be useful to the human body, but in most cases it is harmful. In some forms alcohol may be given by physicians as medicine. Alcohol is also commonly used as an antiseptic. It is rubbed on the skin to kill the germs before an operation is performed. Moreover, tincture of iodine, which is iodine dissolved in alcohol, is widely used to kill the germs in small wounds.

Effects of alcohol on heart and nerves. When alcohol in any form is used in small amounts as a drink, it makes the body functions slower and less effective, and when used in large quantities, it acts as a strong narcotic.[1] However, the first effects that may usually be noticed are the more rapid beating of the heart and the excitement of the nerves. These effects are followed, when a sufficient quantity of alcohol is taken, by a stupor or even unconsciousness.

Effects of alcohol on protoplasm. Alcohol injures protoplasm by withdrawing water from it. Alcohol affects the coverings of nerves so that the nerves cannot act in normal ways. Therefore a person who has taken much alcohol loses the ability to control his mind and body. Many automobile accidents as well as accidents of other kinds are caused by the use of alcoholic drinks.

Effects of alcohol on animals. Many experiments have been made in order to learn the effects of drinking alcohol. In one study the effects upon guinea pigs were observed through a long period of time. It was found that the eyes of these animals and their organs of respiration were harmed when they were given alcohol. They had fewer young. These were less healthy and more of them were deformed or were defective in other ways than of the young of guinea pigs which had no alcohol.

Effects of alcohol on people. Alcohol affects people in important ways: (1) the drinking of alcohol is known to cause some people to become insane; (2) it may cause people to commit crimes; (3) it causes poverty, because people buy alcoholic drinks with money which may be needed for food, clothing, and other necessities, as is shown by the fact that the Society for the Prevention of Cruelty to Children found that 90 per cent of the cases which came to its attention were due to alcohol; (4) it shortens life, as stated by forty-three insurance companies of the United States and Canada, whose studies covered twenty-five years and included two million people, showing that those who drink no alcohol live longer, on the average, than those who have this habit; and (5) it makes it difficult to secure or to hold important positions, because people who drink heavily usually cannot be trusted to do their work well.

[1] *Narcotic* (nar kot'ik): a substance which produces stupor, that is, a dulling of the mind and senses. A person in an extreme stupor is unconscious.

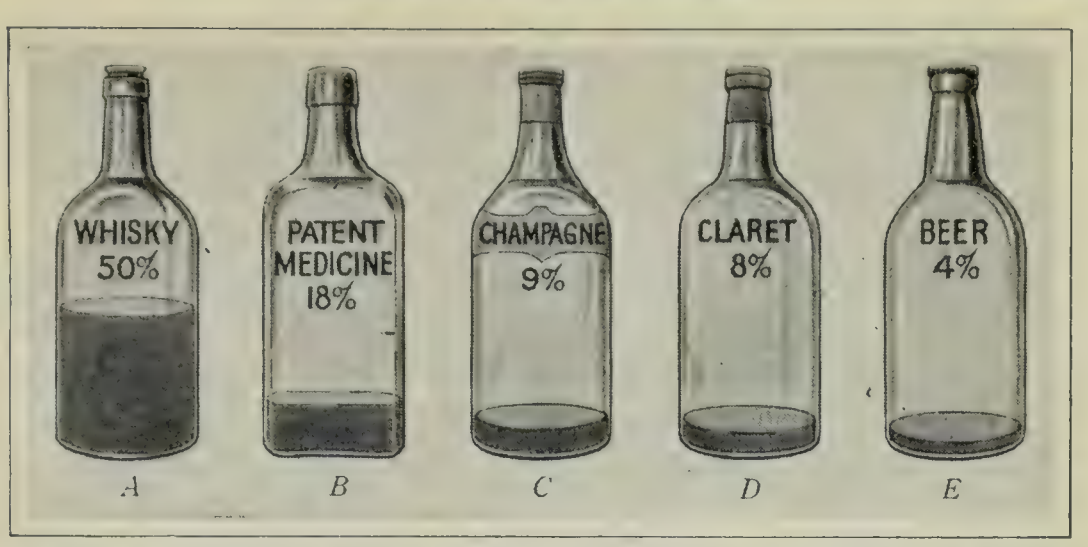


FIG. 415. A comparison of the percentages of alcohol contained in four kinds of liquor and a composite, or combination, of a number of widely advertised patent medicines. Do you think it might be possible to get the habit of drinking from using these patent medicines?

Does alcohol make one warmer? People sometimes drink liquor because they may feel warmer immediately after drinking it. They are really deceived, because the alcohol so affects the nerves that the blood vessels enlarge near the skin and lose their heat faster. Alcohol also reduces oxidation of food within the body and thus reduces the body heat.

Many patent medicines contain a high percentage of alcohol (Fig. 415), and sometimes people who use these medicines form the alcohol habit without realizing that they are doing so.

Tobacco and its effects. ***Experiment 108.*** What effect does tobacco have upon small animals? Place a white rat or white mouse or a guinea pig in each of a pair of jars, leaving the cover partly removed to provide air, and give them water but no food for a day, so that they will be hungry. Then feed both animals fresh lettuce or other fresh food, in one case having sprinkled powdered tobacco thoroughly over the food. Observe to see if both animals eat equal amounts and if any difference in behavior may be observed. Did the animal appear to like the food upon which tobacco was placed? Does the action of the two animals provide positive evidence that tobacco is harmful to this animal?

Place an animal in each of another pair of jars. Water and feed both in the same way. Then cover both jars, leaving a small opening for exchange of air. Start burning a cigarette or cigar in a flame and put

the burning tobacco into one jar. Observe both animals to see any difference in behavior. Remove the animal from the smoke-filled jar as soon as possible after you have completed your observations. Does the tobacco smoke seem to have any harmful effect upon the animal? any useful effect?

In what ways is tobacco harmful? Tobacco is known to be harmful to boys and girls. A recent scientific study showed that cigarette smoke contains several violent poisons, among them carbon monoxide, nicotine, and furfural, a substance more poisonous than alcohol. This study also showed that these poisons are produced in larger amounts when the smoking is rapid and continuous. Another study of more than six hundred men showed that those who smoked a package or more of cigarettes a day were more frequently below normal in weight, and were more often ill with colds and other diseases of the organs of respiration than were other men who smoked less or not at all. Still another study of tobacco smoking showed (1) that smoking usually makes the heart beat faster; (2) that it makes the body reactions, particularly those of the hands, less steady; and (3) that it makes people who are not accustomed to smoking less able than ordinarily to do well in thinking tasks, such as adding and remembering figures. There is, moreover, considerable evidence which shows that as a rule those students who are nonsmokers do better both in their school work and in athletics than smokers. There is no evidence that smoking is helpful to young people.

Habit-forming drugs. Tobacco and alcohol belong in the class of substances called "habit-forming drugs," which includes opium, morphine, and cocaine. The effects of the latter drugs are more harmful than are those of alcohol and tobacco.

Self-test on Problem XXXIII–E. (*Do not write in the book.*) **1.** The use of alcohol *increases* the effectiveness of the body functions.

2. The use of alcohol is responsible for *few* accidents.

3. A drink of alcoholic liquor makes one *more* able to resist cold weather.

4. Tobacco is known to be *harmless* to young people.

5. The use of tobacco seems, in general, to be related to *better* school work.

Self-test on Organization of Facts. Name the important processes of the body, and explain each.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Compare the advantages and the disadvantages of the insect skeletons and the human skeleton.

2. What facts can you state about bones which prove them to be made up of living tissues?

3. Pus in a wound is composed chiefly of the dead bodies of white corpuscles. Why would so many white corpuscles be in a wound? How do you explain the fact that so many are dead?

4. What would be the effect upon the body heat of having too few red corpuscles?

5. What advantages are derived from having the blood pass through the capillaries?

6. Trace the digestion of a meat sandwich, naming the organs through which the food passes and what happens to the food in each organ.

7. Give an original example of an instinct, of a reflex, and of a habit.

Exercises on Scientific Attitudes. 1. What scientific attitude or attitudes did the people lack who laughed at Harvey's announcement of the nature of the circulation of the blood?

2. After each of the next two problems are five comments. Which of these would a scientist consider best? Can you support your choices by quoting one or more of the scientific attitudes (pp. 12 and 13)?

It has been reported by accepted scientific authority that of one thousand men, taken at random, who are moderate drinkers of alcoholic liquors a larger number will live to be ninety years old than of one thousand men who drink no liquor whatever. Some people have concluded from these statements that moderate drinking makes for good health. It has also been reported, on scientific evidence, that of one thousand fat men very few will reach age ninety and that of one thousand of normal weight a much larger number will reach this age.

a. These conclusions are equally sound.

b. The conclusion from the observations on the use of alcohol is probably the sounder.

c. The conclusion from the observation on fat men is probably the sounder.

d. It is likely that neither conclusion is sound.

e. Neither conclusion could possibly be sound.

Several years ago considerable interest was aroused over accounts in the newspapers and pictures in the newsreels of a boy who had been following the practice of smoking several cigars a day from the time he was a baby. The boy was and had always been in excellent health.

a. If smoking were very harmful the boy wouldn't be healthy.

b. This boy is the exception that proves smoking is harmful.

c. I must see the boy before I'll believe he is healthy.

d. I don't believe there was such a boy.

e. He couldn't have smoked so much as they say he did.

3. What scientific attitudes would one who uses tobacco or alcohol need in order to be persuaded to stop its use because of the facts presented in this chapter?

4. What scientific attitudes do the people lack whose unscientific practices are mentioned in "Problems Discussed in this Unit"?

Exercise on Scientific Method (Inventing Experiments). Can you invent an experiment to determine whether plants give off carbon dioxide?

Special Reports. 1. Man has more than ten sense organs. What are they, and where are they located? (Consult a textbook on psychology or on biology.)

2. With a classmate make a demonstration of how first aid should be given in drowning or gas poisoning.

3. What are the various enzymes produced, where are they produced, and what food substances does each digest? (Consult a textbook of physiology or of biology.)

4. What special health laws and regulations are enforced by your local board of health?

5. Are there special laws in your state or province concerning the sale and use of tobacco, alcohol, and narcotics?

6. Secure information from the American Medical Association concerning the values of several widely advertised patent medicines.

7. What useful products can be secured from garbage, and by what processes are they secured?

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COTTLER, JOSEPH, and JAFFE, HAYM. Heroes of Civilization, Book IV. Little, Brown and Company, Boston.

STILES, P. G. Human Physiology. W. B. Saunders Company, Philadelphia.

Chapter XXXIV · How Science Attacks Germ Diseases

Questions this Chapter Answers

How are smallpox, typhoid fever, tuberculosis, diphtheria, and colds successfully combated?
What is natural immunity?
How do disease germs injure the body?
Can animals be protected against certain diseases by inoculations?
How are malaria, yellow fever in man, and cattle fever in cattle caused? How are they prevented?

Problem XXXIV–A · How are Inoculations Used to Oppose Disease?

Progress in combating disease. Bacteria that cause disease in men, in other animals, or in plants have been objects of scientific study for only about sixty years. During that brief period, however, much knowledge of the cause, prevention, and treatment of the various bacterial[1] diseases has been gained. Certain serious diseases, however, are caused not by bacteria but by protozoa (see Glossary). This means that some diseases are caused by plants and some by animals. The causes of still other diseases are not yet known. Science has made and still is making great progress in its study of disease (Fig. 416). Many diseases which formerly were greatly feared and dreaded because of their serious consequences are no longer regarded with general concern, because science has discovered effective ways of combating them.

***Vaccination[2] or inoculation as a protection against disease.** Long before the nature of bacteria or of small animal parasites which produce disease was known, a very important discovery

[1] *Bacterial* (bak te'ri al): having to do with bacteria.

[2] *Vaccination* (vak sin a'shun): the process of inducing a mild form of disease by use of weakened or dead germs or of the products from these germs.

was made by an English physician named Jenner (1749–1823). He noted that those who milked cows which were infected with

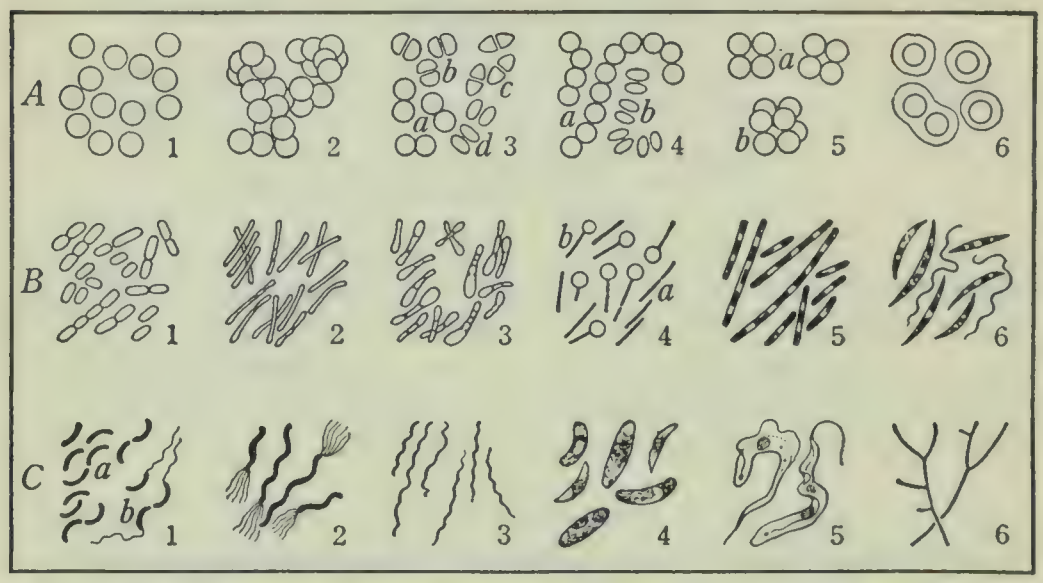
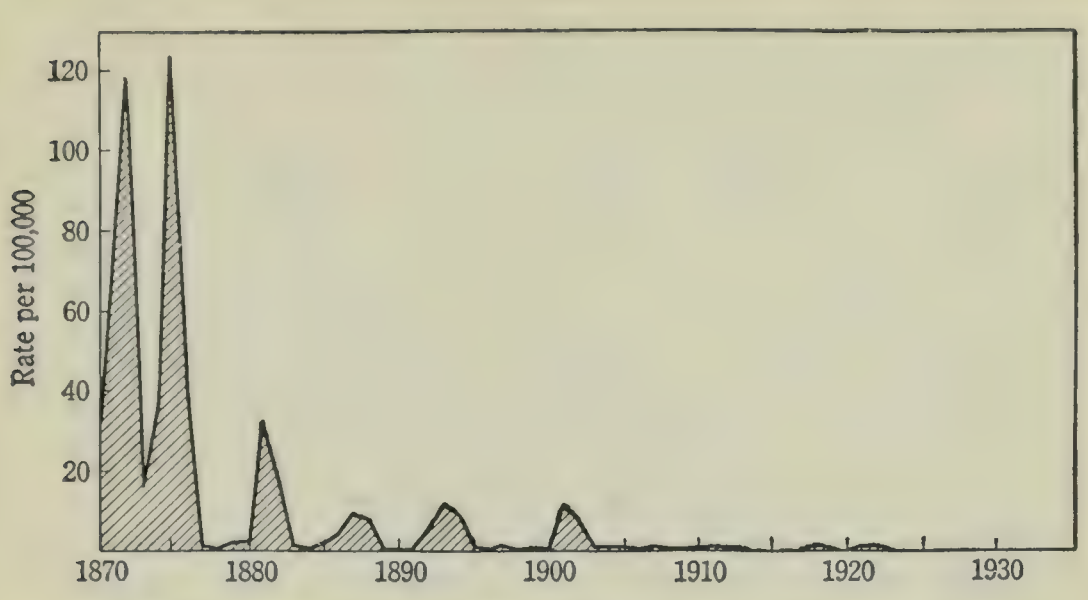


FIG. 416. Types of bacteria and germs. *A*, spherical or coccus forms: 1, cells separate; 2, in masses; 3, *a-d*, in pairs of different kinds; 4, *a* and *b*, in chains of different kinds; 5, *a*, in fours, and 5, *b*, in groups of eight; 6, with thick walls. *B*, rod or bacillus forms: 1, a rod form, causes dysentery; 2, causes tuberculosis; 3, causes diphtheria; 4, *a* and *b*, causes lockjaw; 5, causes glanders; 6, the curved bacilli, usually found with the spiral forms here shown, cause trench-mouth disease. *C*, spiral, and other forms: 1, *a* and *b*, causes cholera; 2, found in water and not a cause of disease; 3, causes intestinal disease; 4, causes malaria (protozoa, not bacteria); 5, cause sleeping sickness (protozoa); 6, threadlike bacteria

a disease called cowpox sometimes took the disease, and that after recovering from it they were immune to smallpox. Some people even advised those who wished to become immune to smallpox to milk cows until they got the cowpox. Jenner transferred a mild form of the disease to human beings by putting some of the material from a cowpox "pock" into a scratch on the skin. A mild attack of cowpox resulted. The person was thereby made immune to both cowpox and smallpox, which are now thought to be the same disease. This process was called vaccination. The process has been improved in methods since Jenner's time, and has become widely used with the result that much of the danger from smallpox has been removed (Fig. 417). Vaccination for smallpox usually gives immunity for about six years. A second vaccination usually gives immunity for life. It is now



Year	Deaths per 100,000	Year	Deaths per 100,000	Year	Deaths per 100,000	Year	Deaths per 100,000
1870	32	1887	9	1903	0.1	1919	0
1871	86	1888	8	1904	0.2	1920	0
1872	119	1889	*	1905	0.2	1921	*
1873	16	1890	0.1	1906	0.1	1922	*
1874	36	1891	0.1	1907	0.2	1923	0
1875	124	1892	5	1908	*	1924	0
1876	40	1893	11	1909	*	1925	0
1877	1	1894	9	1910	0.1	1926	0
1878	0.1	1895	0.4	1911	0.1	1927	0
1879	1.6	1896	0.1	1912	0.1	1928	0
1880	2	1897	0.9	1913	0	1929	0
1881	32	1898	*	1914	0	1930	0
1882	27	1899	0.6	1915	0	1931	0
1883	0.8	1900	0.3	1916	0	1932	0
1884	0.1	1901	11.1	1917	0	1933	0
1885	1.5	1902	8.4	1918	*	1934	0
1886	4						

*Less than 0.05 per 100,000.

NOTE. From 1870 to 1897, statistics for Manhattan, Bronx, and Brooklyn boroughs.

FIG. 417. Death rates from smallpox in New York City, 1870–1934. The graph above the table is made from the facts given in the table. The graph and the table show that in 1870 an average of about 32 people out of every 100,000 in New York City died of smallpox. How many times as many people died of smallpox in New York City in 1872 as in 1912?

thought, although it has not been finally proved, that very small animal parasites and not bacteria are the germs of smallpox.

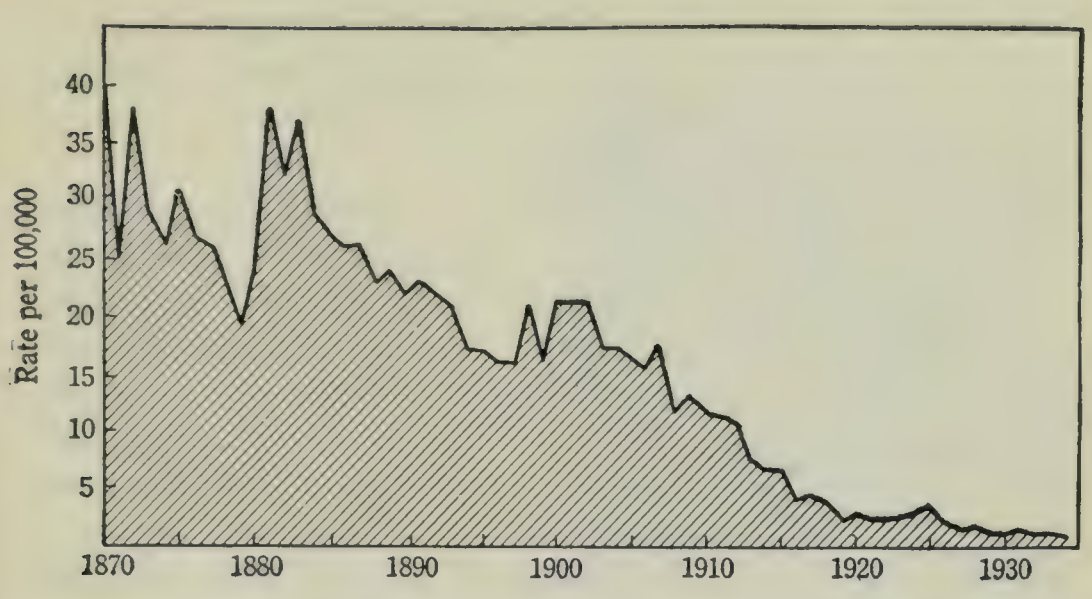
*Vaccination for typhoid fever. The methods of vaccination vary in each disease for which a method of vaccination has been discovered. Immunity to typhoid may be secured by a series of vaccinations with dead typhoid bacteria and their products. Recovery[1] from the slight discomfort of the first vaccination leaves the body better able to meet the second, and recovery from the second prepares for the third. After this the fully active typhoid bacteria cannot get started. The body has become immune (Fig. 418). Such immunity secured by vaccination is thought to last about two and one-half years.

*Colds. Common colds are of several kinds and occur more frequently than any other type of disease. They are spread from one person to another as a result of handling objects that have been used by persons who have colds, or of being too near such persons when they cough or sneeze. Therefore anyone having a cold should not mingle with other people for fear of infecting them. When one coughs or sneezes, he should always cover his mouth and nose with a handkerchief. Towels, drinking cups, eating utensils, and other objects used by people having colds and other diseases liable to be transferred by infection should be boiled before they are again used. The boiling kills the germs.

Inoculations for preventing colds are commonly given, but these are not successful with all people. The best treatment for a cold is rest; one will recover most quickly by remaining in bed, especially if the cold is accompanied by fever.

Tuberculosis. Tuberculosis is usually contracted in childhood. The germs of tuberculosis may be in milk or other food, or when dry may be carried in the air. These germs are widely distributed, and almost all human beings have chances of becoming infected by them. Two facts are highly important in relation to tuberculosis: (1) direct sunlight kills the bacteria causing tuberculosis if they are not dry; (2) the germs cannot grow so as to produce the disease in human bodies that are kept healthy. Tuberculosis is most successfully treated by allowing the patient to rest for months in bed. Abundant food and freedom from worry are also

[1] *Recovery* (re kuv'er y): getting well after an attack of disease.



Year	Deaths per 100,000	Year	Deaths per 100,000	Year	Deaths per 100,000	Year	Deaths per 100,000
1870	40	1887	26	1903	17	1919	2.17
1871	25	1888	23	1904	17	1920	2.41
1872	38	1889	24	1905	16.12	1921	2.12
1873	29	1890	22	1906	15.34	1922	2.17
1874	26	1891	23	1907	17.15	1923	2.31
1875	31	1892	22	1908	11.99	1924	2.97
1876	27	1893	21	1909	12.18	1925	3.15
1877	26	1894	17	1910	11.66	1926	1.72
1878	23	1895	17	1911	11.18	1927	1.19
1879	19	1896	16	1912	10.06	1928	1.30
1880	25	1897	16	1913	7.17	1929	1.11
1881	38	1898	21	1914	6.50	1930	.89
1882	32	1899	16	1915	6.35	1931	1.09
1883	37	1900	21	1916	4.07	1932	.89
1884	29	1901	21	1917	4.24	1933	.95
1885	27	1902	21	1918	3.57	1934	.59
1886	26						

NOTE. From 1870 to 1897, statistics for Manhattan, Bronx, and Brooklyn boroughs.

FIG. 418. Death rates from typhoid fever in New York City from 1870 to 1934. The graph above the table is made from facts in the table. The graph and the table show that in 1870 an average of about 40 people in every 100,000 in New York City died of typhoid fever. About how many times as many died of this disease in New York City in 1870 as in 1934?

essential. Some progress has been made in combating and preventing tuberculosis by inoculations with weakened living germs.

***Natural immunity.**[1] When for any reason a person is protected against a particular disease, he is said to be immune to that disease or to possess immunity to it.

*There are many people who will not develop a certain disease even if they have neither had the disease nor been vaccinated or otherwise given protection against it. For example, some people never have had the mumps, though they have often been exposed to those who had the disease. They are naturally immune, since their bodies are able to prevent the growth of the organisms (as yet unknown) which produce the mumps. A few persons are naturally immune to measles. This kind of protection is called natural immunity. Natural immunity usually lasts throughout life, but cases are known of persons who were immune to such diseases as mumps and measles most of their lives and then fell victims to them in their old age.

***How are germ diseases caused?** The most common way in which diseases are produced may be illustrated with diphtheria.

If the germs of diphtheria are grown in a glass tube containing a proper food solution, and if after two or three days they are all killed and the liquid in which they have grown is introduced into the body of a young person who has never had diphtheria, he will probably show all the signs of having the disease even though he has received no diphtheria bacteria. This is explained by the fact that as the diphtheria bacteria grew in the liquid they produced poisonous substances known as toxins. It is these toxins that cause the disease. Whenever enough of the toxins are introduced into the body, the disease follows. Toxins are special products of the life processes of germs, just as carbon dioxide and various other substances are produced in the processes of human nutrition. Each kind of disease germ produces its own particular kind of toxin.

***How does the body combat diphtheria?** During the time when a person is sick with diphtheria his body, in overcoming the

[1] *Immune* (im mune′): free from or protected against. *Immunity* (im-mu′nity): the condition of being immune, usually applied to freedom from disease.

toxins, develops substances which counteract[1] the effects of the toxins. These counteracting substances are known as antitoxins. If enough antitoxin is present in the blood, the germs cannot grow and thus cannot produce toxins.

Preparation and use of diphtheria antitoxin. The knowledge of the nature and values of antitoxins provided the means of fighting diphtheria. It was learned that horses and mules, although naturally immune, can be treated with diphtheria toxins and, by successive treatments, develop a high degree of resistance to the disease. In this way diphtheria antitoxin came to be prepared from the blood serum of these animals and made constantly available for any outbreak of the disease (Fig. 419).

FIG. 419. Securing diphtheria antitoxin from a horse. The horse receives the best of care, and everything having to do with the removal of the serum is done with the same care as would be observed with a human patient in a well-conducted hospital. What sanitary measures to insure cleanliness are shown here?

When given at the beginning of an attack of diphtheria, antitoxin saves nearly all those who receive it. But the longer the time that passes before it is given, the smaller are the chances that the patient will recover. Thus if the antitoxin is not given until after the fifth day, over 50 per cent are lost. The toxins have then become too abundant for the prepared antitoxin to be very useful.

Other methods of combating diphtheria. The invention of the Schick test provided another weapon for the war on diphtheria.

[1] *Counteract* (kown ter akt'): to act against, or in opposition to, another action.

A little toxin injected under the skin indicates whether or not a person is immune to diphtheria. Those who are not immune can be made so by injecting toxin-antitoxin under the skin. Toxin-antitoxin consists of a mixture of toxin with almost enough antitoxin to neutralize it.

The use of antitoxin since 1895, of the Schick test in 1913, and of toxin-antitoxin a little later have together practically removed the danger from diphtheria (Fig. 420).

Inoculating animals. Some of the methods of protecting people from disease by inoculation are used to protect animals. In vaccinating hogs to make them immune to hog cholera another plan is commonly used. Weakened but living bacteria and a small amount of antitoxin are given at the same time. As the bacteria begin to grow, the presence of the antitoxin enables the animal to counteract the toxins and to produce its own antitoxins, thus producing immunity. Sometimes only antitoxin is given, with the aim of protecting the animal against possible natural infection. This is not so effective as the double vaccination.

***Summary.** Immunity to disease is either natural or acquired. Immunity can be acquired either (1) by recovering from the disease, or (2) by various methods of vaccination or inoculation.

Self-test on Problem XXXIV–A. (*Do not write in the book.*) **1.** Most people are made immune for life to smallpox by being vaccinated _ _(?)_ _ times.

2. Vaccination for typhoid fever gives immunity lasting about _ _(?)_ _ years.

3. Germ diseases usually injure the body by *antitoxins* produced by the germs.

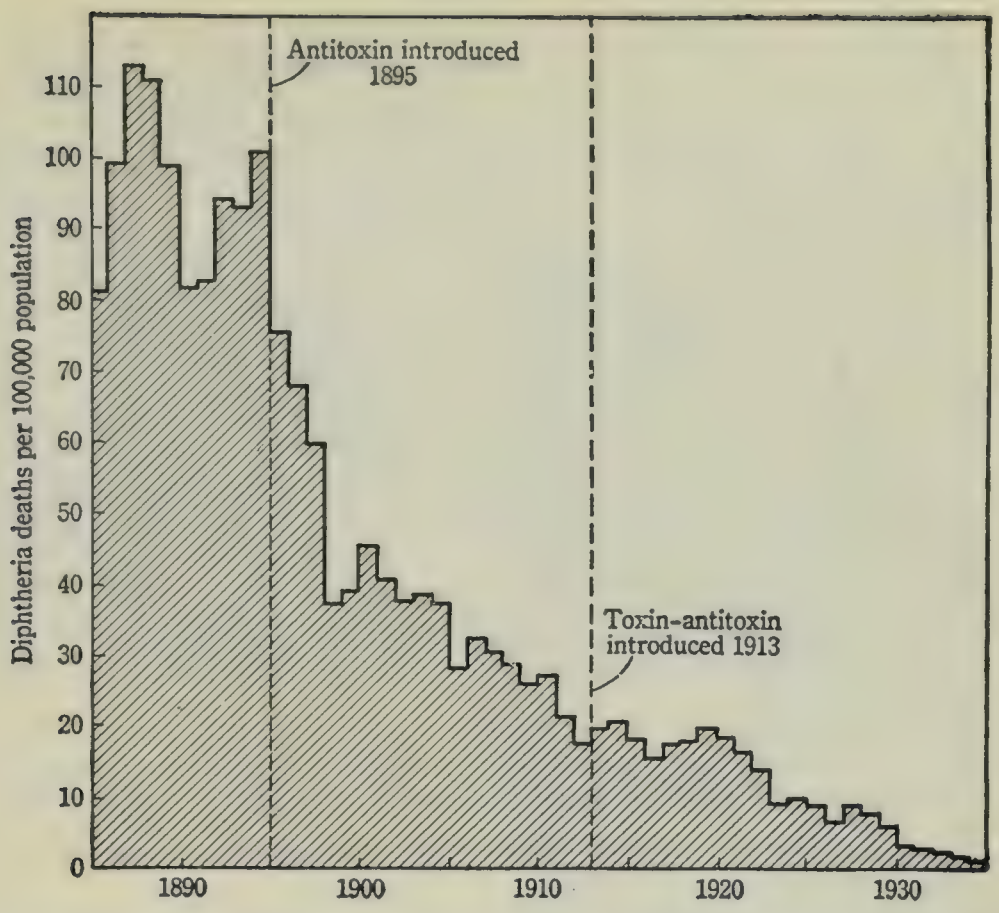
4. A disease which is prevented by a series of inoculations is (1) diphtheria; (2) smallpox; (3) mumps; (4) typhoid fever; (5) measles.

5. The body resists germ diseases by producing *serums* which counteract the poisons produced by the germs.

6. Diphtheria antitoxin is secured chiefly from *cows*.

7. One can usually be made immune to diphtheria by injections of *antitoxin*.

8. A disease which is cured by the use of antitoxins is (1) smallpox; (2) colds; (3) typhoid fever; (4) cowpox; (5) diphtheria.



Year	Deaths per 100,000	Year	Deaths per 100,000	Year	Deaths per 100,000	Year	Deaths per 100,000
1885	81.2	1898	37.2	1911	21.1	1924	9.5
1886	99.2	1899	38.9	1912	17.2	1925	8.6
1887	113.2	1900	45.4	1913	19.3	1926	6.1
1888	110.7	1901	40.5	1914	20.6	1927	8.1
1889	98.9	1902	37.4	1915	17.9	1928	7.1
1890	81.7	1903	38.8	1916	15.2	1929	5.3
1891	82.6	1904	37.3	1917	17.3	1930	2.7
1892	94.4	1905	28.0	1918	17.4*	1931	2.2
1893	93.0	1906	32.1	1919	19.9	1932	2.1
1894	101.1	1907	30.3	1920	18.1	1933	1.1
1895	75.1	1908	28.1	1921	15.9	1934	1.0
1896	67.9	1909	25.8	1922	13.3		
1897	59.6	1910	26.6	1923	9.0		

*Civilian deaths only.

FIG. 420. Death rate from diphtheria in the state of New York, 1885–1934. The graph above the table is made from the facts of the table. The graph and the table show that in 1887 an average of about 113.2 people out of every 100,000 in New York State died of diphtheria. How many times as many died in New York State from this disease in 1885 as in 1934?

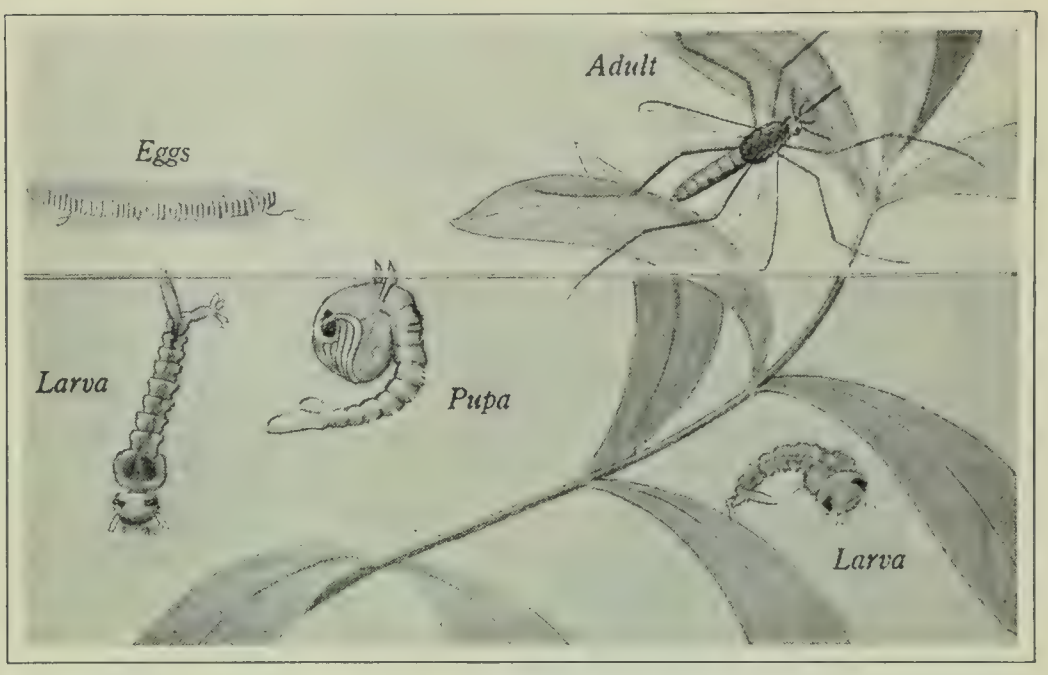


FIG. 421. The four stages in the life history of the common mosquito. The life histories of the malarial and yellow-fever mosquitoes are similar to this. Compare the life history of this mosquito with that of the housefly. (See "To the Student," p. xvi)[1]

Problem XXXIV–B · What are Other Means of Combating Diseases Caused by Animal Parasites?

***Malaria.** The disease called malaria or malarial fever, formerly very common, is produced by a small one-celled animal parasite. This germ completes part of its life in a human host and during the other part of its life lives in the body of a certain kind of mosquito (Fig. 421). When a mosquito carrying the malaria germ bites a human being, the germ enters the person's blood, where it rapidly produces many of its kind. It lives in the red blood corpuscles and uses them as its food. Whenever a large number of the young parasites escape from the corpuscles into the liquid of the blood, the sick person has a "chill." If this person takes quinine, it enters the serum of the blood and may kill the parasites. Malarial mosquitoes with no malarial germs may get them by biting people who have malaria and may then carry the germs to well people.

[1] From Powers, Neuner, and Bruner's *This Changing World.*

***Yellow fever.** Yellow fever also is thought to be caused by an animal parasite which is introduced into human beings by the bite of a certain kind of mosquito.

*Both yellow fever and malaria may be prevented by avoiding bites from the kinds of mosquitoes which carry the disease germs. The surest plan is to destroy the breeding places of the mosquitoes that carry these germs. This may be done either by draining the lakes, pools, or other places where there is standing water in which the mosquitoes develop or by pouring crude oil or kerosene on the water. The oil prevents the young mosquitoes from getting air and thus kills them.

Local, city, state, and national health officers are charged with the responsibility of helping to get rid of the kinds of mosquitoes that carry disease germs.

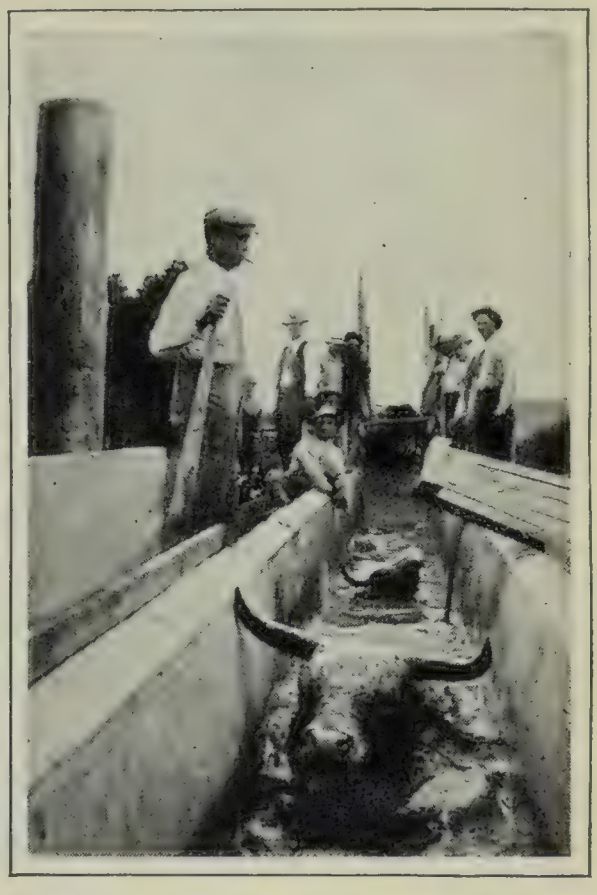


FIG. 422. Dipping cattle to destroy the cattle tick. In what respect is the cattle tick competing with man for the available food supply? Can you state a principle which relates to this last question?

Cattle fever. The cattle tick, common in the southern part of the United States, is a small insect which carries the germ of cattle fever. It bites through the skin of cattle and feeds on the blood. Thus the germs are transferred to the blood of the cattle and produce this disease. The germs can live for long periods within the ticks, and therefore these insects are a constant danger in the warmer parts of the United States. The cattle may be protected from the tick by dipping them entirely in a liquid containing an insect poison (Fig. 422). This process should be repeated as often as the ticks appear. Another most interesting

method of preventing this disease consists in developing a breed of cattle with skin so thick that the ticks cannot bite through it.

Self-test on Problem XXXIV–B. (*Do not write in the book.*) **1.** The malarial germ is transferred to the blood as the result of the bite of a certain kind of infected (1) fly; (2) louse; (3) flea; (4) bedbug; (5) tick; (6) mosquito.

2. The yellow-fever germ is believed to be *a bacterium.*

3. The germ of cattle fever is transferred to the cattle by the bite of an infected (1) fly; (2) mosquito; (3) louse; (4) bedbug; (5) flea; (6) tick.

4. All germ diseases are caused by *saprophytes.*

5. It is the business of _ _(?)_ _ to see that local rules of disease prevention are enforced.

6. Smallpox may be entirely prevented if _ _(?)_ _ is properly done.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What arguments would you advance to convince people that the members of a family should not drink from the same glass or use the same towel?

2. More children of parents sick with tuberculosis take the disease than children whose parents do not have tuberculosis; yet nobody is ever born with tuberculosis. How do you explain these facts?

3. How do you explain the fact that the connection between germs and the diseases they cause has been so recently discovered?

4. Why does a person who is going to travel in Europe or Asia frequently have inoculations of several kinds before he goes?

Exercises on Scientific Method. 1. When Joseph Lister (1827–1912), the great English surgeon, first began his work in a hospital, he was appalled at the terrible loss of life from wounds and surgery. He did not believe, as did the other surgeons with whom he worked, that the oxygen of the air caused the wounds to become infected. After reading the accounts of Pasteur's work on fermentation, he formed the opinion that germs in the air, and not oxygen, caused the infections. Upon learning that carbolic acid would kill the odor of sewage, he reasoned that carbolic acid would also prevent infections in wounds, because infected wounds smelled like sewage, and hence the odor must be caused by germs in the sewage and in the wounds. He made a mild solution of carbolic acid, and with it saturated bandages which he kept over the wounds. Infections did not develop in these wounds.

What phases of scientific method (p. 9) are illustrated by the steps in Lister's study and his discovery regarding the problem of wound infections?

2. Louis Pasteur (1822–1895) was a French scientist. With his microscope and careful, exact methods of study he proved that bacteria float in the air and if they are kept out of foods no decay will follow. He proved that fermentation may be caused by yeasts from the air. He saved the silk industry of France by finding the germs that killed the silkworms. He found how to control the germ of chicken cholera, which took 10 per cent of the French fowls every year. A disease called anthrax was killing cattle and sheep. Pasteur found how to prepare vaccines and to treat the animals so that they became immune. Hydrophobia, fatal to man, was conquered by vaccine prepared by Pasteur. A boy, Jufille, was bitten by a mad dog while trying to protect some younger children. Pasteur treated the boy and he recovered. Fig. 423 shows Jufille, now a man, beside the monument to Pasteur. The antitoxins used today have been developed upon Pasteur's foundation work.

Fig. 423. **Exercise on Scientific Attitudes:** What scientific attitudes (pp. 12 and 13) does even this brief account of Pasteur's scientific work indicate that he possessed?

Find in an encyclopedia or a history of science a complete account of one of Pasteur's studies of disease. Which of the scientific methods (p. 9) are illustrated by various steps in his experimenting?

3. Can you tell which of the steps in the following account of Jenner's discovery of the value of vaccination illustrate using controls, inventing hypotheses, making conclusions from data or facts, and inventing experiments?

1. Jenner noted that milkmaids who contracted cowpox were later immune to smallpox.

2. He wondered whether cowpox and smallpox were not the same disease.

3. He observed that smallpox broke out in the village following an outbreak of cowpox.

4. This was evidence, he thought, that cowpox and smallpox were the same disease.

5. He vaccinated his own boy with cowpox.

6. When the boy recovered without becoming sick, Jenner inoculated him with matter from the sores of a child sick with smallpox. The boy remained well.

7. Jenner decided that vaccination with material from either cowpox sores or smallpox sores made people immune to smallpox.

8. After eight years of study and experiment on the problem of vaccination, he vaccinated a healthy boy and later inoculated him with smallpox. The boy did not take smallpox.

9. Most people in civilized countries accepted vaccination as a means of preventing smallpox.

Exercises on Scientific Attitudes. 1. METCHNIKOFF (1845–1916), a great Russian biologist, observed that the Bulgarians are an unusually long-lived people. In trying to discover the reason for this fact he searched for something in their living conditions which was different from the living conditions of all other peoples. He found that the Bulgarians drink more buttermilk than other peoples. He therefore concluded that the drinking of buttermilk was responsible for the long lives of the Bulgarians, and that if other peoples were to adopt the custom of drinking as much buttermilk as the Bulgarians, they would live as long as the Bulgarians.

Does Metchnikoff's conclusion seem to you to be sound? Can you support your decision by quoting one or more of the scientific attitudes (pp. 12 and 13)?

2. Some people believe that if a person will carry a piece of asafetida in a little bag around his neck, he need never fear becoming sick with scarlet fever. These people can tell you the names of others who have carried such bags and have never had scarlet fever.

Which of the scientific attitudes most closely relates to this belief?

Special Reports. 1. Secure from your city or state health department the published records of the amount of diphtheria, smallpox, and tuberculosis in your city or state for the past ten years. Prepare a report showing what has been done and what should be done to combat diseases.

2. Tell the story of the discovery of the cause of yellow fever.

Chapter XXXV · Foods and their Uses

Questions this Chapter Answers

How did early food habits differ from those of the present?
Why do we need food?
What are the sources and the needs served by the energy and the non-energy foods?
How is the body like an engine?
What is a balanced diet, and how is it secured?
Why are bulky foods a necessary part of the diet?
What is the value of milk and sugar as foods?
How are foods preserved?
What are food substitutes and adulterants?
What is the value of such laws as the Pure Food and Drugs Act?
What values are obtained from cooking foods?
Are expensive foods most valuable?

Problem XXXV–A · What are the Classes of Foods, and What Purpose does Each Class Serve?

Early foods and food habits. The practice of having three regular meals a day is a relatively modern one. It was only after food became fairly abundant and after it became known that the body works best with several meals of smaller amounts rather than an occasional very large meal that this practice came into use. Probably the first men ate whenever they had a chance to get food. Since wild vegetables were usually easier to get than animal food, it is likely that vegetables made up the regular diet and that animals were an irregular part of it. It is likely also that when primitive men procured animal food, they sometimes ate many pounds of raw meat at a meal. The smaller and less desirable animals, such as snails, clams, mussels, and insects, were not hard to catch. The more desirable ones, such as squirrels, deer, bear, and buffalo, were harder to secure and probably were hunted actively only when hunger for meat became pressing (Fig. 424).

Our needs for food. There are three main services performed by food: (1) building up the body by replacing worn-out parts;

(2) providing the materials for growth, and (3) providing energy by means of which the work of the body is done.

A. M. N. H.

FIG. 424. Ancient man and his prey. Scientists have discovered from a few fossil remains how ancient man must have looked. What scientific attitudes (pp. 12 and 13) did these scientists need in solving this problem?

Anything that can be used by the body for building new parts, for growth, or for supplying energy may properly be called a food. These foods are compounds made almost wholly from ten chemical elements, though some other elements are found in the body in small amounts. The ten elements are carbon, hydrogen, oxygen, nitrogen, calcium, potassium, magnesium, sulfur, phosphorus, and iron. Silicon and chlorine compounds also are usually found in both plants and animals. It is not fully known whether all the other elements found in the body are necessary. Possibly some of them are brought in with food material and deposited in the body without serving any useful purpose.

The energy foods. The compounds made from these elements make up three groups of foods: (1) the sugars and starches, or carbohydrates, usually secured from ripe fruits, potatoes, rice, and white bread; (2) the fats, usually secured from milk, butter, oleomargarine, peanuts and other nuts, peanut butter and other nut-food preparations, oil dressings for salads, and fat meats; (3) the proteins, usually secured from such sources as beans, peas, lentils, bread, eggs, lean meat, and fish. Mineral substances such as salt, lime, and iron compounds are needed and are supplied in milk, vegetables, and fruits, or they may be added, as is done by using salt (Fig. 425).

Experiment 109. How may one determine whether a given food contains protein? To find a test for a given substance it is necessary to have both a test substance and a control. In this experiment take

FIG. 425. What foods containing each of the three groups of energy foods are shown here? What foods shown here contain minerals?

for the test substance one like white of egg, which we know contains a considerable amount of protein, and for the control take a substance like sugar, which we know contains no protein at all. Boil in a test tube a sample of each in a little water; then add to each a small amount of nitric acid. After a few moments add a little ammonium hydroxide, *a drop or so at a time.* What do you observe in each test tube? The effect you observe indicates the presence of protein. Make a protein test now of a number of food substances, such as bread, beans, honey, meat, milk, and others.

Experiment 110. How may one determine whether a given food contains sugar? For the test substance in this case use a sugar, such as glucose, and for the control use a substance, such as egg white, which we know contains no sugar. Put into one test tube a little of the glucose and into another a little of the egg white. Add water; then heat equally both test tubes. Add to each a few drops of a mixture of Fehling's solutions A and B. What do you observe in each test tube? Any substance containing sugar will act like the glucose in this test when treated in this way. Make the test, therefore, of a number of foods, such as meat, bread, candy, beans, peas, cheese, and others.

Experiment 111. How may one determine whether a given substance contains fat? Use for the test substance something which you know contains fat, such as lard or butter. Use for the control something which you know does not contain fat, such as a cube of sugar. Rub each sample upon a sheet of paper; then hold the paper toward the light. What happens with each sample? Test various food substances for fat.

For the starch test see photosynthesis (Experiment 90, p. 542). Record the results of these tests in the following table:

FOOD TESTS

Name of food	Protein	Sugar	Starch	Fat
White of egg	+	−	?	?
Sugar	−	+	?	−
Lard	?	?	?	+
Cheese	?	?	?	?
_____	?	?	?	?
_____	?	?	?	?

Add the names of the other foods which you tested, placing in each column a + if the food contains the substance indicated and a − if it does not. Compare your results with those obtained by other members of the class. In all cases where different members disagree, the tests should be carefully repeated until all are sure which are the correct answers.

Experiment 112. What changes does saliva bring about in starch? Put into your mouth a small pinch of cornstarch. Does the starch change in flavor after it has been for a few seconds in your mouth? Remove the starch and the saliva, placing an equal amount in each of three test tubes. Put a little starch into each of three other test tubes for controls. Test the contents of the first test tube and of one control for starch; then test the contents of the second test tube and of the second control for sugar; and finally test the contents of the third test tube and of the third control for protein. Answer the question in the problem.

Experiment 113. What kinds of foods are stored in roots? Test such fleshy roots as parsnips, beets, turnips, radishes, and carrots to determine which of the energy foods they contain. Make a table which summarizes your findings.

The body like an engine. The needs and uses of food in the body may be compared with the needs and uses of fuel in a machine, such as an automobile. The comparison cannot be carried too far, else it may not be accurate. For example, the body can

use the digested foods to replace and build up worn-out cells, but the automobile must go to the repair shop for the repairing or replacing of worn-out parts.

The energy foods are compounds that contain carbon and hydrogen. Gasoline is likewise a compound that contains carbon and hydrogen. In the automobile engine gasoline vapor and the oxygen that is mixed with it explode in the cylinder when the oxygen combines with the gasoline. The energy thus released drives the pistons, thus causing the car to move. In the living protoplasm of every cell, oxygen combines with the various compounds, and energy is released, by means of which all kinds of work are done. In both the automobile engine and in living cells the burning of fuels (gasoline or food) results in releasing heat energy and in giving off as waste products water and carbon dioxide (see Fig. 408, p. 607).

Warren Boyer

FIG. 426. How many reasons can you give to explain why these boys need more of protein and carbohydrate foods than do adult office workers?

*What does each class of energy foods provide? When work is done, part of the protoplasm of the cells is broken up. When hard work is done with the muscles, more protoplasm is broken down than when hard desk work is done (Fig. 426). Since protoplasm is a protein, the body needs protein foods to build up the protoplasm that has been used while work was being done and also to build new protein for growth. The sugars and starches and other carbohydrates are used chiefly for the energy they contain. Surplus sugar is stored in the tissues, especially in the liver. Carbohydrates are also used for making fats and proteins. Fats are used directly as foods or are stored in the body for later use.

Food Value of an Average Serving of Certain Food Materials[1]

Food	Measure	Calories			Total Calories
		Protein	Fat	Carbohydrate	
Apple	½ large	2	3	45	50
Asparagus	4 stalks, 4 in. long	3	1	6	10
Bacon	4–5 small slices	13	87	...	100
Banana	1 medium	4	4	67	75
Beans, dried	¼ cup	45	8	118	171
Beans, lima, dried	¼ cup	42	8	150	200
Beans, lima, fresh	½ cup	23	5	72	100
Beans, string, fresh	½ cup	3	1	11	15
Beef, lean, round	2 slices, 4 × 3 × 1¼ in.	96	104	...	200
Beets	½ cup, cubes	3	1	21	25
Blackberries	½ cup	9	16	75	100
Boston brown bread	½ in. slice, 3 in. diam.	7	6	54	67
Bran, wheat	¼ cup	8	3	43	54
Bread, graham	1 slice, 3½ × 2 × ⅜ in.	5	2	26	33
Bread, white	1 slice, 3 × 3½ × ½ in.	7	3	40	50
Butter	pat, 1 T.[2]	1	99	...	100
Buttermilk	½ pt.	29	12	48	89
Cabbage, chopped	½ cup	2	1	7	10
Cake, sponge, 2 eggs, hot water	1 piece, 3 × 2¾ × ¾ in.	11	10	129	150
Cantaloupe	½ melon	3	...	47	50
Carrots, cooked	2 medium	4	2	34	40
Cauliflower	½ small head	5	3	12	20
Celery	¼ cup	2	...	4	6
Cheese, American	cube, 1 in.	23	63	3	89
Cheese, cottage	3⅔ T.	49	2	11	62
Cherries, stoned	¼ cup	1	2	22	25
Chicken, roast	1 slice, 4 × 2½ × ¼ in.	51	49	...	100
Corn, canned	½ cup	11	11	78	100
Corn, fresh	1 ear, 6 in.	6	4	40	50
Corn meal, cooked	⅔ cup	10	5	85	100
Cream, thin	2 T.	2	43	5	50
Dandelion greens	½ cup	12	11	52	75
Dates, unstoned	3–4	2	7	91	100
Egg white	1	13	1	...	14
Egg, whole	1 egg	25	45	...	70
Egg yolk	1	11	45	...	56
Figs	3 large	10	2	188	200
Fish, lean, broiled	1 slice, 4 × 2½ × 1 in.	81	52	...	133
Gingerbread, plain	1 piece, 2 × 1⅔ × 2 in.	14	42	144	200
Grapefruit	½ large	7	4	89	100
Grapes, white	22	5	15	80	100
Ham, boiled	1 slice, 4¾ × 6 × ⅛ in.	44	106	...	150
Honey	1 T.[2]	1	...	99	100

[1] Compiled from various sources: M. S. Rose, *Laboratory Handbook for Dietetics*; M. S. Rose, *Feeding the Family*; H. C. Sherman, *Food Products*; and others.

[2] T. = Tablespoonful.

FOOD VALUE OF AN AVERAGE SERVING OF CERTAIN FOOD MATERIALS

Ice cream	⅔ cup	13	202	105	320
Lamb chop, broiled	1 chop	40	60	...	100
Lamb, roast	1 slice, 3½ × 4½ × ⅛ in.	41	59	...	100
Lettuce	½ head	3	2	7	12
Liver, calf's, broiled	medium-sized serving	62	38	...	100
Macaroni, cooked	½ cup	7	1	42	50
Maple sirup	2 T.	...	...	133	133
Milk, whole	½ pt.	34	88	48	170
Molasses	2 T.	4	...	129	133
Mutton, roast	1 slice, 3 × 3¾ × ⅛ in.	33	67	...	100
Oatmeal, cooked	⅔ cup	11	11	45	67
Olive oil	1 T.	...	100	...	100
Olives, green	4 medium	1	41	8	50
Onions	3 to 4 medium	13	6	81	100
Orange	1 medium	5	2	68	75
Orange juice	½ cup	...	...	50	50
Oysters, raw	½ cup	37	18	20	75
Peaches	3 medium	6	3	91	100
Peanuts	20–24 single nuts	19	63	18	100
Peas	⅔ cup	14	2	34	50
Peas, dried	⅜ cup	70	6	177	253
Pecans	12 meats	5	87	8	100
Pineapple	2 slices, 1 in. thick	4	6	90	100
Pork chop, lean	1 chop	64	136	...	200
Potato, sweet	1 medium	12	10	178	200
Potato, white	1 medium	11	1	88	100
Prunes	4 medium	3	...	97	100
Raisins	¼ cup	3	9	88	100
Rhubarb	1 cup	2	7	16	25
Rice, white, steamed	½ cup	9	1	90	100
Sirup, corn	1¼ T.	...	...	100	100
Spinach, cooked	⅝ cup	3	2	20	25
Squash, cooked	½ cup	4	5	46	55
Strawberries	¾ cup	5	7	38	50
Sugar	1 T.	...	...	50	50
Tomato, fresh	1 small	4	4	17	25
Turnip, cubes, raw	½ cup	3	1	21	25
Veal leg, lean, broiled	1 serving	105	45	...	150
Walnuts, English	8–16 meats	11	82	7	100

The number of Calories one needs varies not only with one's work but also with age and sex. Thus, a child two years of age needs about 900 Calories per day, and this number increases at about the rate of 100 Calories for each year until the child is twelve. Between twelve and fourteen years a girl needs about 2100 Calories per day. A girl of fifteen or sixteen and a boy of thirteen or fourteen need about 2400 Calories. A boy of fifteen or sixteen needs about 2700 Calories. One author states that about one sixth of the Calories should be supplied by proteins, about one fifth by fats, and the rest by carbohydrates. From these facts and those in the table above prepare some daily diets which would serve for boys and girls of various ages

How is a balanced diet secured? It is clear, therefore, that a diet should include foods from each of these three groups of energy foods if all the needs of the body are to be met. The proportion of fats required for young people is less than for fully grown people. Fats furnish 9.3 Calories (see Glossary) of heat energy for every gram eaten. Starches and proteins furnish each 4.1 Calories for every gram eaten.

Not only should the mixed diet include foods from each of the three groups, but it should be properly balanced in quantity from each group. It is not possible to state exactly what this balance is for all people. Each must find what proportion is best for himself. Each meal, however, should include proteins from some such foods as soups, meats and fish, beans and peas, and rye or whole-wheat bread. It should also include carbohydrates from fruits, potatoes or carrots or other vegetables, jelly, and desserts. The needed amounts of fats and sugars are likely to be present in these foods in sufficient amounts. This is true if sugar is used in preparing fruits and desserts.

Vitamins. This group of "body regulators" has been known for only a few years. They are not yet well understood, but are known to be of great importance. Sources of the vitamins and the effects they produce in the body are known, but scientists have not yet found how they produce these effects (Fig. 427).

Sources of vitamins. Certain foods and patent medicines are widely advertised as being especially valuable because they contain certain vitamins. It is not necessary to buy these products in order to secure necessary vitamins, because vitamins are found in so wide a variety of common fruits and vegetables that an ordinary well-balanced diet is likely to supply all one needs. There is value, however, in adding to the daily diet, especially of city dwellers, cod-liver oil, halibut-liver oil, salmon-liver oil, or viosterol. These supply vitamin D and in part at least make up for the lack of sunshine which produces vitamin D by its action on the skin.

Home-cooked or canned fruits and vegetables? One frequently sees the statement in magazine articles and in advertising that canned fruits and vegetables supply all the needed vitamins as effectively as home-cooked fruits and vegetables. These statements are without scientific foundation. Vitamin B is destroyed

rapidly when the food containing it is heated above the boiling point of water, as it is during the processes of commercial canning.

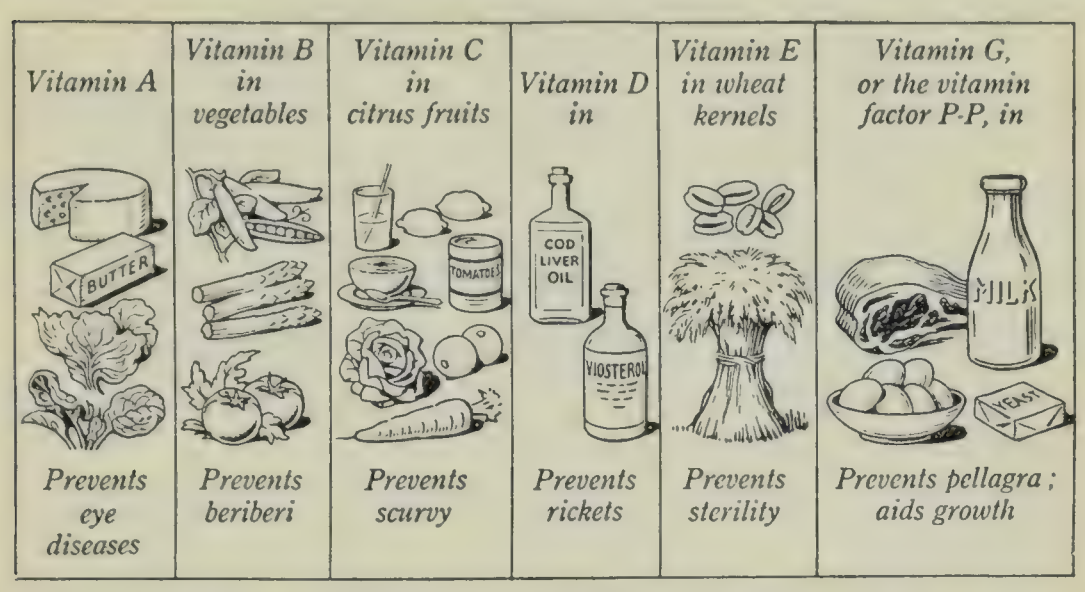


FIG. 427. Can you name other sources of vitamins than these shown here? (Modified from a drawing in *Science News Letter*)

It is better, therefore, to eat fresh, home-cooked fruits and vegetables than canned ones. If, however, fresh fruits and vegetables cannot be obtained, vitamin B must be supplied along with the canned foods.

Dried foods as sources of vitamins. It has been found that raw foods, such as apples and vegetables, lose much of their vitamin content when they are kept for some time before they are eaten. To save as much as possible of the vitamins in such foods, therefore, it is best to can them by the cold-pack method immediately after they are harvested.

Mineral salts. The body, especially the bones, contains salts of the elements sodium, potassium, calcium, magnesium, iron, chlorine, phosphorus, sulfur, carbon, fluorine, and bromine. The diet must therefore supply the needed small quantities of these salts. An ordinary well-balanced diet will usually supply all that are needed. Foods that are especially rich in mineral compounds include milk, bread, egg, spinach, raisins, prunes, beef, cabbage, and apples.

Water. Water is a necessary part of the diet. Practically all foods contain water, but usually not enough for our needs. It

is not necessary, however, as was formerly believed, to drink "at least six glasses of water a day." The best rule to follow is to drink when you are thirsty as much as you want.

*Summary. Foods are needed for growth and repair of body tissues and for energy. Proteins alone provide for growth and replacement of protoplasm. Proteins, together with fats and sugars, furnish energy. Fats are the chief heat-producing foods. Necessary non-energy foods are vitamins, mineral salts, and water. A well-balanced diet, which includes fruits and vegetables, will usually serve all the body's needs.

Self-test on Problem XXXV–A. (*Do not write in the book.*) **1.** The energy foods are ___(?)___, ___(?)___, and ___(?)___.

2. A food which is rich in carbohydrates is (1) meat; (2) butter; (3) olive oil; (4) bananas; (5) eggs.

3. A food rich in fats is (1) oranges; (2) potatoes; (3) rice; (4) lemons; (5) olive oil.

4. A food rich in protein is (1) oranges; (2) potatoes; (3) milk; (4) olive oil; (5) watermelon.

5. People who do hard work need larger quantities of (1) fats; (2) proteins; (3) starches; (4) sugar; (5) carbohydrates, than people who do light work.

6. Young people who are still growing need more (1) fats; (2) sugars; (3) proteins; (4) carbohydrates; (5) starches, than grown people.

7. Select from the following list the foods which are likely to contain vitamins, and also those which are likely to be rich in minerals: (1) milk; (2) dried apples; (3) green vegetables; (4) cod-liver oil; (5) eggs; (6) canned vegetables; (7) water; (8) salt; (9) beef.

Problem XXXV–B · What are Some Important Foods, and What is their Relation to Diet?

Concentrated or bulky[1] foods? There is little danger of urging too strongly the importance of using fruits and vegetables in our daily food. For ages the human body had to secure its nourishment (in large part at least) from bulky materials such as plants and parts of plants. In doing this the structures and habits of

[1] *Bulky* (bul'ky): occupying much space.

the digestive [1] system became fitted to the tasks of securing food from these bulky materials. Therefore we are not properly fed

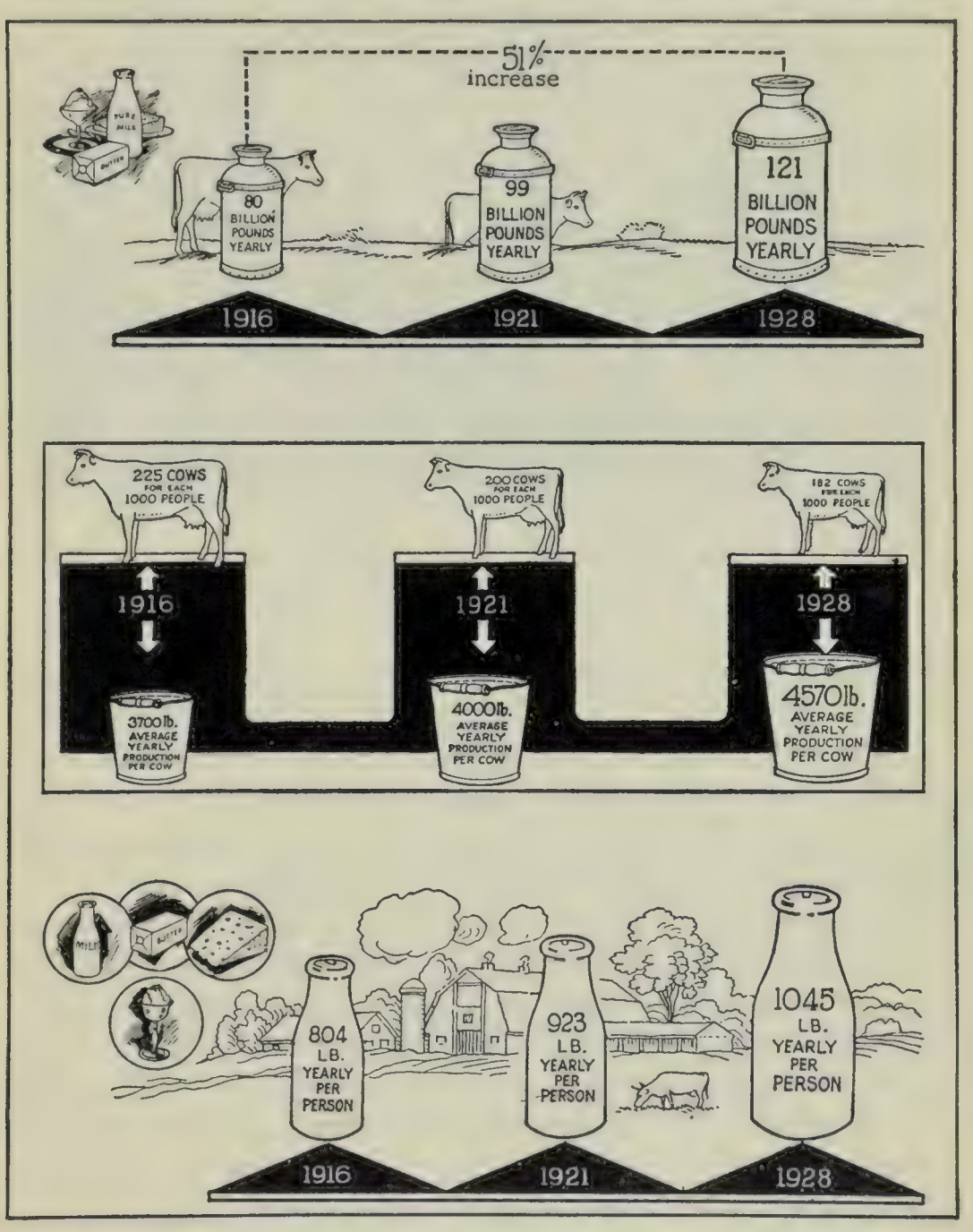

51% increase
80 BILLION POUNDS YEARLY
99 BILLION POUNDS YEARLY
121 BILLION POUNDS YEARLY
1916
1921
1928
225 COWS FOR EACH 1000 PEOPLE
200 COWS FOR EACH 1000 PEOPLE
182 COWS FOR EACH 1000 PEOPLE
3700 lb. AVERAGE YEARLY PRODUCTION PER COW
4000 lb. AVERAGE YEARLY PRODUCTION PER COW
4570 lb. AVERAGE YEARLY PRODUCTION PER COW
804 LB. YEARLY PER PERSON
923 LB. YEARLY PER PERSON
1045 LB. YEARLY PER PERSON

FIG. 428. What three important facts are illustrated in this picture?

when we have all our needed nourishment in the most concentrated [2] form. We could have all our meals consist of protein in

[1] *Digestive* (di jes'tiv): having to do with digestion.

[2] *Concentrate* (kon'sen trate): to put much in a small space.

FIG. 429. Delivering milk in Granada, Spain. List the advantages and the disadvantages in this method of delivering milk

the form of extracts of meat, beans, and peas; all our vegetable juices in concentrated vegetable jellies and stews; all our fats in pure lard and butter. We could even add the welcome flavoring extracts and salt and pepper to these concentrated foods. Such an arrangement, however, would not give us satisfactory meals, because the necessary bulk would not be supplied.

The importance of milk. Milk is used all over the world and by all classes of people (Fig. 428). Indeed, the name *mammals* refers to the structures which produce the milk. The young of all animals except mammals must depend upon foods other than milk.

Milk contains sugars, fats, and proteins in forms that are most readily digested and absorbed. The butter in milk contains vitamins G and A. Milk also contains valuable minerals, especially calcium. Calcium is necessary for building and repairing bone tissues. Unless a physician has advised that a special diet should be used, every pupil of school age should drink milk every day. Even those adults who do not drink milk should use it in their other foods.

Raw milk and pasteurized milk. Milk delivered to customers without treatment is known as raw milk (Fig. 429). When such

milk can be had from healthy cows and clean dairies, it is to be preferred to milk in any other form. Careless handling of raw milk, however, has been the means of distributing the bacteria which cause throat infections, typhoid, scarlet fever, and other diseases.

Experiment 114. Does pasteurized milk remain sweet longer than raw milk which has not been pasteurized? First sterilize two bottles thoroughly by boiling them for twenty minutes; then put absorbent cotton in the mouth of each and put them aside to cool. Put some raw milk into a beaker and heat it over the burner, stirring it constantly with a thermometer and keeping it constantly at 145° F. (about 62° C.). After thirty minutes pour the milk you have just pasteurized into one of the sterilized bottles and pour an equal quantity of raw milk into the other bottle. Put fresh absorbent cotton in the mouth of each bottle. Cool the milk in each bottle to about 50° F. (10° C.) by allowing cold water to run over the outside of the bottle. Examine the milk in both bottles from time to time to find out which keeps sweet longer. Answer with a complete statement the question asked at the beginning of this experiment.

Exercise on scientific method (isolating the experimental factor). The one condition which is different in the two bottles of milk is the experimental factor. What is the experimental factor?

Milk which is not safe should be pasteurized; that is, it may be heated until it reaches a temperature of from 142° F. to 145° F., kept at that temperature for thirty minutes, and then promptly cooled to at least 50° F. This process kills most of the harmful bacteria without greatly reducing the food values of the milk. Pasteurizing small amounts of milk may be done most safely by using a pan of water in which the milk bottles are stood upon a false bottom that will raise them above the bottom of the pan. The milk should not be allowed to boil, since boiling cooks it and thus causes changes in the food values of the milk.

Sources of milk. For the youngest mammals, including human beings, the mother's milk is likely to be best. The supply of the mother's milk in most animals is limited, and with human beings it is often not sufficient for the proper growth of the baby. For this reason, and in order to have milk for drinking and cooking, it has been necessary to secure milk from several kinds of animals. In this country cows are the chief source of milk. In Italy and some

other European countries goats are kept for their milk. This practice has recently become fairly common in the United States also. In Palestine it is not uncommon to see sheep used for their milk. In some of the Spanish countries the milk of donkeys is used. The water buffalo is the chief milk-producing animal in Egypt, India, China, and many other countries.

FIG. 430. Collecting the sap of the sugar maple tree, very early spring in Vermont. Through what structures of the tree stem does the sweet sap ascend from the roots?

In some of the countries which do not have satisfactory ways of keeping the milk cool, the milk animals are led or driven about the city streets. When a person wants to buy milk, the milkman stops his herd, milks the desired amount, delivers it, and then moves his herd on to his next customer. This "direct from producer to consumer" method has some advantages, but far more disadvantages.

Sources of sugar. The human race seems always to have had a "sweet tooth." This is natural, since a proper amount of sugar is a necessary part of one's diet. A balanced diet, however, requires that an excess of sugar, like an excess of any food substance, be avoided, because it tends to produce excess fat and with some people to have more serious effects. The earliest settlers in this country found it difficult to secure enough sugar. Honeybees, which were brought from Europe, provided but a limited supply of honey. The sugar-maple tree in springtime provided a sweet sap which could be boiled and thus evaporated until a thick sirup [1] was produced (Fig. 430); or the sirup could be boiled until the water

[1] *Sirup* (sir'up): a thick, sweet liquid made by dissolving sugar or by evaporating the water from sweet sap.

was evaporated and solid sugar was left. The people of the Southern states learned to make molasses and sugar from sugar cane.

Sugar cane and sugar beets are the chief modern sources of sugar. In the southern part of the United States, in Cuba, in the Philippines, in the Hawaiian Islands, and in many other tropical countries sugar cane is one of the most important crops. The growth of sugar beets, moreover, has become one of the leading farming interests in many of the central and Western states, as it is in Germany, France, and other countries with temperate climates.

Self-test on Problem XXXV–B. (*Do not write in the book.*) **1.** In general, raw milk is likely to contain *fewer* disease germs than pasteurized milk.

2. Milk furnishes *two* of the three classes of energy foods.

3. Milk contains *four* of the vitamins.

4. Milk is produced by the group of animals called _ _(?)_ _.

5. Name three plants which produce sugar.

Problem XXXV–C · How is Energy in the Form of Food Preserved for Future Use?

Food-preserving a modern practice. Ancient men made no plans for the future. They accepted conditions as they found them. If they were fortunate enough to secure food they ate; if not, they went without.

As men advanced in knowledge, a knowledge gained by experience, they began to think ahead to future needs. They learned to save for a later time, when they might perhaps be more hungry, part of both the animal and the plant food they secured. In the warmest parts of the earth foods of some sort may have been available all the year. If men wished to live away from the tropics, however, they *must* look forward to the season when animals might be less abundant and less desirable for food than in the summer. One by one the various ways of preserving food which we now know were invented. These are effective because they prevent or delay the decay which bacteria, yeasts, and molds produce.

A, W. S. Carlson

FIG. 431. *A*, how the Eskimos dry fish and meat; *B*, how raisins are made from grapes in California. What disadvantages would there be in laying the meat on a rock or board and in hanging up the bunches of grapes to dry?

***Methods of preserving food.** Drying (or dehydrating) was an early method of preserving. The Eskimos and Indians still dry fish and game in great quantities (Fig. 431, *A*). Other peoples learned to dry the flesh of almost all kinds of meat-producing animals. Drying is also used in preserving many kinds of fruits and vegetables (Fig. 431, *B*). Organisms which produce decay in food cannot live and reproduce actively without moisture. In drying, almost the whole food content is preserved.

*Salt is much used in preserving meats. Salt extracts the moisture from the bacteria and other small organisms by osmosis. Thus germs either are killed or are at least prevented from multiplying rapidly and from carrying on their life activities effectively.

Preserving by salt may cause the meat to become hard, but soaking it in water before cooking it will remove most of the salt and also will soften the tissue. Salted meats are sometimes smoked. Other meats are dried and smoked at the same time. The smoke added to the salt helps to preserve the meat and also adds a desirable flavor. The salting and smoking of "country-cured meat" are slow processes. Many people, however, prefer meat which has been so cured to that preserved by the more rapid salting with salt solutions and the smoking with chemicals, which is accomplished by use of compressed air in large meat-packing establishments.

*Canning as a means of preserving is based on the principle of heating the food sufficiently to kill bacteria, yeasts, and molds, and then closing the can or jar airtight while hot, so that no new bacteria, yeasts, or molds may enter. Almost all kinds of foods are now preserved either in glass or in tin cans. Canning establishments are now found all over the country wherever foods are produced. Thus much food which would otherwise be spoiled and lost is saved. The canning of food makes it possible for people to have a wide variety of foods at all times of the year in all parts of the world. Also we may know and use many kinds of foods which our grandparents never knew.

Refrigeration is a favorite means of preserving. At low temperatures bacteria reproduce less rapidly and are generally less active. Meat-packers regularly keep in cold storage large quantities of meat, eggs, and butter.

Food preservatives. Foods should not contain any preserving substances (preservatives) harmful to the human body. Formaldehyde or any other poisonous substance used to prevent growth of bacteria and molds is likely also to be harmful when eaten in foods. Milk is sometimes treated with small amounts of certain chemicals, especially formaldehyde. When milk that is left for a day at a temperature of about 70° F. does not sour, the health officer should be asked to determine whether preserv-

ing substances have been used. Sugar, spice, salt, and vinegar are considered harmless preserving substances for food.

*__Food substitutes and adulterants.__[1] It is often possible to use instead of one food another which has about the same food value but costs less, or which may be secured when another cannot be had. A food to be used instead of another is called a food substitute, as when oleomargarine is used for butter. The substitute may be quite acceptable as a food and may be colored or flavored to look or taste like the article for which it is substituted. Many substitutes of chemical origin are now sold.

*When a food is mixed with a substance which changes its nature or its uses as a food, it is said to have been adulterated. Thus when what is sold as coffee is partly coffee and partly other plants, the coffee is adulterated.

__The Pure Food and Drugs Act.__ There is a United States Pure Food and Drugs Act, and many states have separate laws which demand that manufacturers shall label their food articles so as to show just what these contain. The labels for substitutes and adulterated foods are often so worded that many purchasers do not really know that they are buying substitutes or adulterated foods.[2] In some states the laws do not fully protect the public or are not enforced by the local authorities.

__Preparation of food.__ Some people prefer such meats as fish, oysters, clams, ham, and dried beef uncooked. Dried meats, however, sometimes contain dangerous animal parasites such as trichina and tapeworm, and dangerous bacterial parasites of various kinds. To avoid danger from such parasites, therefore, meats should be well cooked.

The materials and the methods used in preparing foods have changed greatly since colonial days in the United States (Fig. 432). Also, the diet of the American people has changed greatly during the last ten years. More fresh fruits and vegetables and less meat are being eaten. Salads of raw vegetables and fruits, besides fur-

[1] *Adulterant* (a dul'ter ant): an impurity put into foods or other materials to reduce the cost of manufacture.

[2] Consumers' Research, Washington, N. J., is an organization which operates without profit for the purpose of investigating foods and other commodities to determine quality and value. Anybody may secure this information by paying a small fee for membership in the organization.

Frederick Bradley

FIG. 432. The kitchen in the Van Cortlandt Mansion, New York City. The kitchen has been restored so as to look as it did in the days of the Revolution. All the cooking was done in the fireplace. **Special Report:** Cooking in colonial times

nishing vitamins and providing bulk, add much to the pleasure of eating if they are skillfully prepared and attractively served. The cooking of foods demands skill and care if it is to serve its purposes (1) of improving the flavor, (2) of making tough meats and coarse-fibered vegetables more easily digested by softening their tissues, and (3) of killing harmful parasites and germs which often find their way into foods. The best diet includes both raw and cooked foods.

Food costs and food values. Fortunately the most nourishing foods are not necessarily the most expensive. Protein foods usually cost more than carbohydrates and fats. Some of the cheaper cuts of meat are as nourishing as the choicer cuts. Eggs, milk, and cheese are usually cheaper sources of protein than meat, and have the additional advantages of containing vitamins which most cuts of meat lack.

Self-test on Problem XXXV–C. (*Do not write in the book.*) **1.** Name five ways of preserving foods, and tell why each method is effective.

2. A harmful food preservative is (1) vinegar; (2) formaldehyde; (3) salt; (4) spice; (5) sugar.

3. When ground grain is added to sausages, the grain is a food *substitute.*

4. When corn oil or cottonseed oil is used in place of olive oil, these substances are food *preservatives.*

5. The truth can be learned about the quality and purity of foods from __(?)__, located at __(?)__.

6. State three advantages derived from cooking food.

7. A proper diet should contain cooked food *but not* raw food.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Compare methods of cooking in colonial times with those used today. (See "To the Student," p. xvi.)

2. Can you suggest how scientists have learned what they know about the food of ancient men?

3. People can become seriously ill with beriberi, pellagra, scurvy, or rickets; yet these are not diseases of the same kind as smallpox and diphtheria. Explain.

Exercises on Scientific Method (Inventing Experiments). 1. Can you plan an experiment to prove that saliva acts on starch but not on fat?

2. Can you plan an experiment by which one might determine the effect on rats of leaving one of the energy foods or one of the vitamins out of the diet?

Special Reports. 1. What is meant by the terms "Grade A milk," "Grade B milk," "certified milk"?

2. How is dried milk, "tinned milk," or "canned milk," prepared?

3. What is meant by the term "a good dairy cow"?

4. The water is a very important source of food. How many foods can you find in your local stores and markets which came from the ocean, from rivers, and from lakes?

5. Consult your grocer and prepare a list of food adulterants and of wholesome food substitutes.

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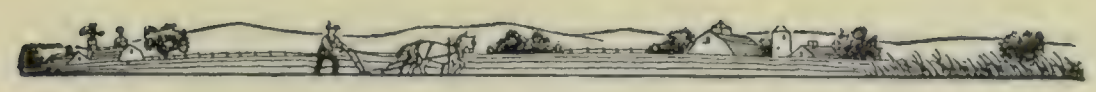
Rose, M. S. Feeding the Family. The Macmillan Company, New York.



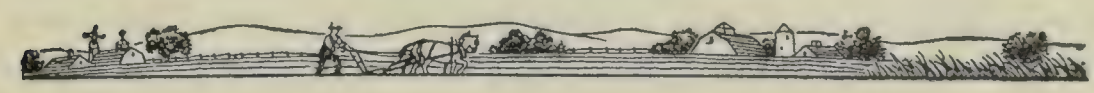
UNIT XIV · *Garden, Farm, and Forest*

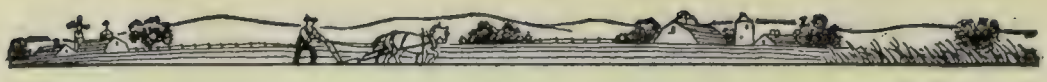
PROBLEMS DISCUSSED IN THIS UNIT

It is probable that men lived on the earth for thousands of years before they learned how to cultivate crops of plants. Nobody knows certainly what kinds of plants they first learned to raise or what crude farming methods were used. As men progressed in their slow advance toward civilization they learned more effective ways of farming and invented implements to make the work easier and better. At length somebody found that a sharp-pointed stick dragged along the ground for a plow made planting easier than digging with the hand. Probably it was many centuries later that the Indians learned that corn grew better when a dead fish had been put into each hill along with the seeds than when the seeds had been planted with no dead fish. This was an early use of fertilizers. In some parts of the world the methods of farming even today seem to us primitive. Agriculture as practiced by the most progressive farmers, however, is a highly developed science and one in which new scientific advances are constantly being made.

Ancient man probably supplied many of his needs from the forests. From them he secured fruits, berries, nuts, and roots as well as animals for food. Later, when he had learned to use fire, he used sticks and tree limbs for fuel. The forests of today are of very great value and will probably be of increasing importance. The problems discussed in this unit are these:

How does man help and control the changing of the sun's energy into food energy?
How is farming carried on in regions where there is little rainfall?
How are certain plants and animals important to farming and gardening?
What is the importance of flower gardens?
What are some important values of trees and forests?
How are trees and forests used and conserved?





Chapter XXXVI · Farm and Garden

Questions this Chapter Answers

What purposes are served by cultivating the soil?
What are the construction and the purpose of cold frames?
How are garden plants transplanted?
How is the soil made fertile and kept fertile?
How is acid soil made fit for farm crops?
In what ways do the kinds of crops which will thrive depend on the nature of the soils?
How are crops harvested and stored?
How may yards be made beautiful by thoughtful planning and planting?
How is farming carried on by irrigation and dry farming in dry regions?
What are some destructive plant and animal pests of farm and garden?
What are some plants and animals which directly or indirectly help the farmer?
How do certain bacteria improve the fertility of soils?

Problem XXXVI–A · How does Man Help and Control the Changing of the Sun's Energy into Food Energy?

The importance of agriculture. Agriculture is the most necessary of all industries. It provides the food supply of the world and hence is the basis of all other industries. Agricultural products are, moreover, the basis of our national wealth. Scientific farming is a career of great importance.

Preparing and tilling the soil. Plant roots need air, water, and organic compounds from the soil. Therefore the roots of plants grow slowly in poorly tilled soils. If, however, the tilling is thorough enough so that air, moisture, and the needed soil substances are readily available, the roots will supply these constantly to the plant, and growth may be rapid. The best farmers cultivate the ground before the crops are planted in order to make sure that the soil is mellow and that the seed bed is in a condition favorable for the growth of young plants.

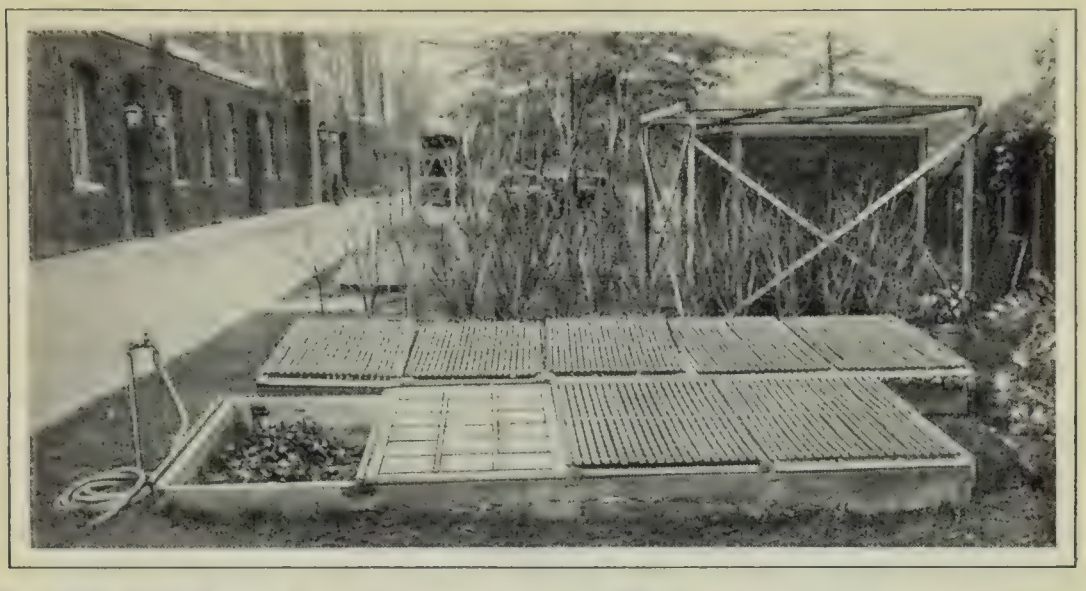


FIG. 433. Cold frames for early-season plants. The frame in front has one section uncovered, one covered with glass, two covered with both glass and wooden slats. The rear frame is entirely covered. What is the purpose of the glass covering? of the added slat covering?

*When the plants appear above the ground, cultivation must continue. Weeds — plants which are not wanted — grow along with the desired plants. Weeds use part of the soil moisture and soil compounds which we should prefer the crop plants to have. They may also spread their leaves over those of the desired garden or field crops and thus cut off the sunlight. Cultivation, therefore, is a means both of keeping the weeds out and of keeping the soil mellow so that crop plants may have proper moisture and air.

Starting the garden. Many kinds of garden plants should be started before they are placed in the garden. In this way they may have a month or more of growth before the season permits outdoor planting. Thus an earlier crop may be produced. Tomato plants, cabbage, lettuce, and other plants may be started from seed in pots or in boxes in the schoolroom or the home; or small outdoor beds may be covered with glass frames above the seeds planted in the soil. Such devices are called cold frames (Fig. 433). Not only are they used to start plants for later garden planting, but large cold frames are used for maturing small garden plants, such as lettuce and radishes, for household use.

Seed-testing. Indoor planting in pots and outdoor cold-frame planting are also used to test a few seeds from those later to be

planted, to make certain that they will germinate and grow into strong plants when the regular outdoor planting is done.

Transplanting. Transplanting young plants into the garden must be done with care. The plants should be separated so as not to break their roots. Holes in the mellow soil should be made, and the roots should be carefully spread in the bottom of the hole. Fine soil should then be spread lightly over the roots, and water should be poured in to cause the soil to settle closely about the young roots. Then more fine soil should be placed about the plant to make sure that it stands upright while its roots are growing.

Garden plants such as radishes, lettuce, and turnips often need to be thinned by removing the less vigorous ones, in order to give the rest more room and more materials for growth.

When plants are grown singly in small pots, all the earth within the pot can be transplanted with the plant. This makes an early start more certain.

Keeping the soil fertile. Plants must have favorable soil materials in order to grow at their best (Fig. 434). The Indians grew crops in one place for a while, and when the soil began to be less fertile they took new fields in other places. The early white settlers did much the same as long as there were unused rich lands to be had. When the level plains were first plowed, men thought the soil would always be fertile. They thought that the fertility of a top layer several feet deep of loam rich in humus could never be exhausted. That time has passed, and they have begun to learn that successful farming depends in large part upon keeping the soil fertile.

How may soil be improved? Since the crops take materials from the soils, the soils must become poorer each year unless fertilizers are added. There are several ways of improving the soil: (1) As much as possible of the refuse of each crop should go back into the soil. (2) Certain crops, such as clover, alfalfa, and cowpeas may be planted. These add to the soil's fertility for reasons which will be discussed later. (3) Plowing a green crop into the soil is of great value in supplying humus. (4) Adding barnyard manure is a sure means of enriching the soil. (5) Prepared fertilizers may be purchased and used when manure cannot be had.

Agricultural Experiment Station, New Brunswick, N. J.

FIG. 434. Wheat plants with different amounts of nitrogen compounds. The soil in the check pot received no nitrogen compounds. In numbers 2 and 4 nitrogen compounds were readily available. In numbers 6 and 8 nitrogen compounds were slowly available. **Exercise on Scientific Method (Using Controls): How many controls are there in this picture? Explain**

Acid soils. When crops have grown on a piece of land for several years, it sometimes happens that acids have slowly collected. Acid in the soil is one of the most common causes of loss of fertility. Certain weeds, such as sour dock and sheep sorrel, which grow well in acid soils, are often regarded as an indication that the soil has become sour. When soils are acid, lime or finely ground limestone should be spread over the ground and worked into it. The lime, which is a base (see Glossary), combines with the acid, changing it to a salt which does not hinder crop growth (Fig. 435).

Relation of soils to crops. In regions of mountains or hills the soil is likely to contain gravel or rock and is not likely to contain large amounts of humus. In plains or river valleys less rock and more humus are likely to be found. In regions that once were swamps there are likely to be large amounts of humus and small amounts of gravel, sand, or clay. These different kinds of regions

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FIG. 435. The alfalfa on the left was grown with lime added to the soil while that on the right was grown without lime. **Self-test on Scientific Attitudes:** What scientific attitudes (pp. 12 and 13) does the farmer possess who allows himself to be convinced by evidence such as this?

usually produce crops of plants that are somewhat characteristic of the regions themselves. Thus, the mountain or hill regions are better adapted for trees and pastures or grazing lands. The plains and valleys are better suited for growing the grain crops, such as corn, wheat, and oats, and for cotton and sugar beets. The soils which were once swamps are better for gardens or for truck crops such as celery and onions. Sandy soil is suitable for peanuts and sweet potatoes. Of course all these regions may be used for growing many plants besides those mentioned. In each region there are added such crops as those found in orchards and vegetable gardens. Soil which is mostly clay is of little value for crops and is likely to be sour.

Harvesting and storing crops. In many countries, even today, grain crops are harvested by hand. The grain is beaten out or is trampled out by men or animals. Contrast with this primitive method the modern use of the combine. This machine is both a harvester and a thresher. Drawn by horses or mules or by a tractor, it cuts the wheat, threshes it, sacks it, and ties the sacks. Harvesting machines of different types are used for other crops.

Much of the grain and beans which the farmer does not need to keep for his own use is now stored in bulk in great grain elevators which are located in places convenient to railroads or ships. It does not follow, however, that all primitive methods should be discarded, because in some places modern methods are impossible.

Making the yard beautiful. Landscape-garden planning and planting offers a great opportunity as a life occupation, just as do agriculture and vegetable gardening. Each location and each climate has its own special problems, which must be solved if the most attractive results are to be obtained. Shrubs and trees have their part in the scheme, as do grassplots, drives, walks, and beds of flowering plants. In general, (1) trees and shrubbery belong at the back or sides of the area that is to be planted, (2) grassplots should occupy the main central spaces, (3) walks and drives should lead almost directly but gracefully to and from the places that they connect, (4) low shrubs and flowering plants should be arranged here and there along the walks, drives, and property boundaries,

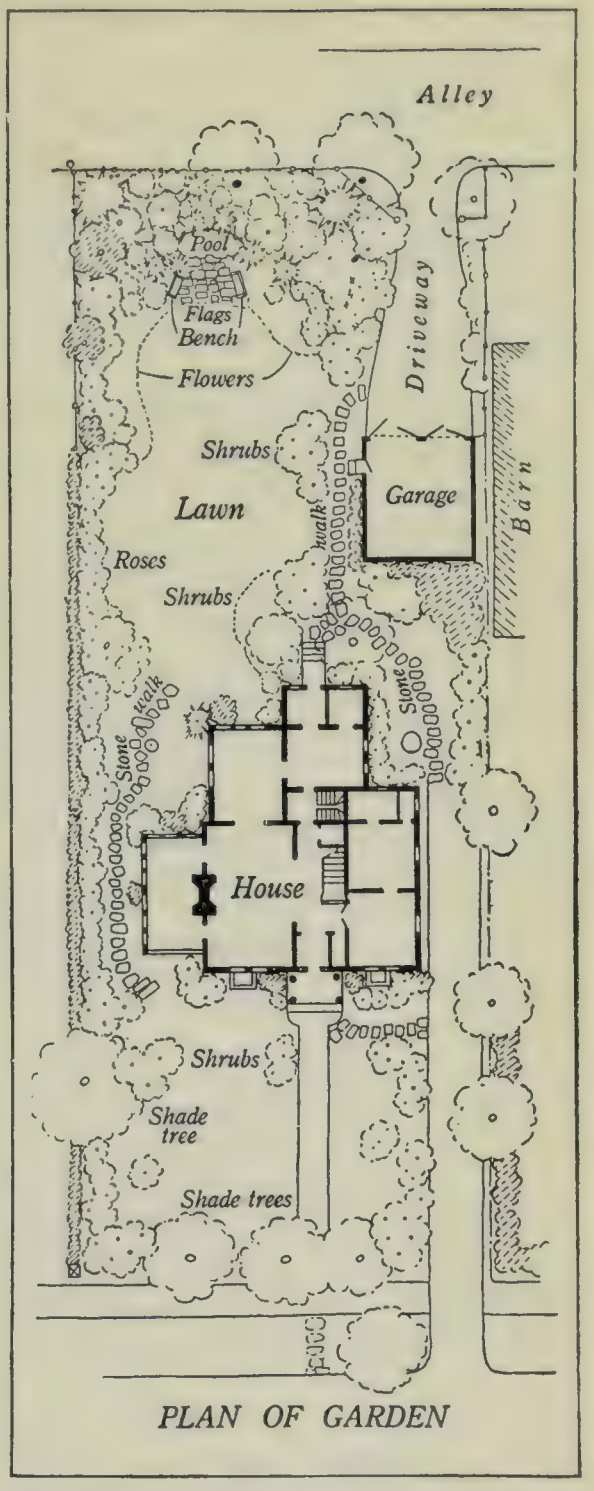


FIG. 436. A landscape architect's plan. Which of the rules for such planting are illustrated here?

and (5) a few shrubs, vines, and wild flowers should be placed along the walls of buildings to add a touch of grace and beauty.

No detailed rules can be made to apply to all landscape regions. Each must be planned as a unit so as to make the best use of its own spaces and peculiar surfaces and to meet its own building needs (Fig. 436). In many cases it is desired to combine a vegetable garden with the landscape plan so as to make a unit of the whole setting for the home.

Self-test on Problem XXXVI–A. (*Do not write in the book.*) **1.** The chief purposes of tilling soil are to supply the plants with __(?)__, __(?)__, and __(?)__.

2. An example of a weed is (1) a potato plant in a flower garden; (2) a rosebush in a flower garden; (3) a water plant in an aquarium; (4) a clover plant in a lawn; (5) a radish in a vegetable garden.

3. *Most* crops take from the soil certain substances which must be restored in order to keep the soil fertile.

4. The acid in soil can be neutralized by (1) adding manure; (2) adding prepared fertilizers; (3) growing clover in the land; (4) adding ground limestone; (5) putting fish in the soil.

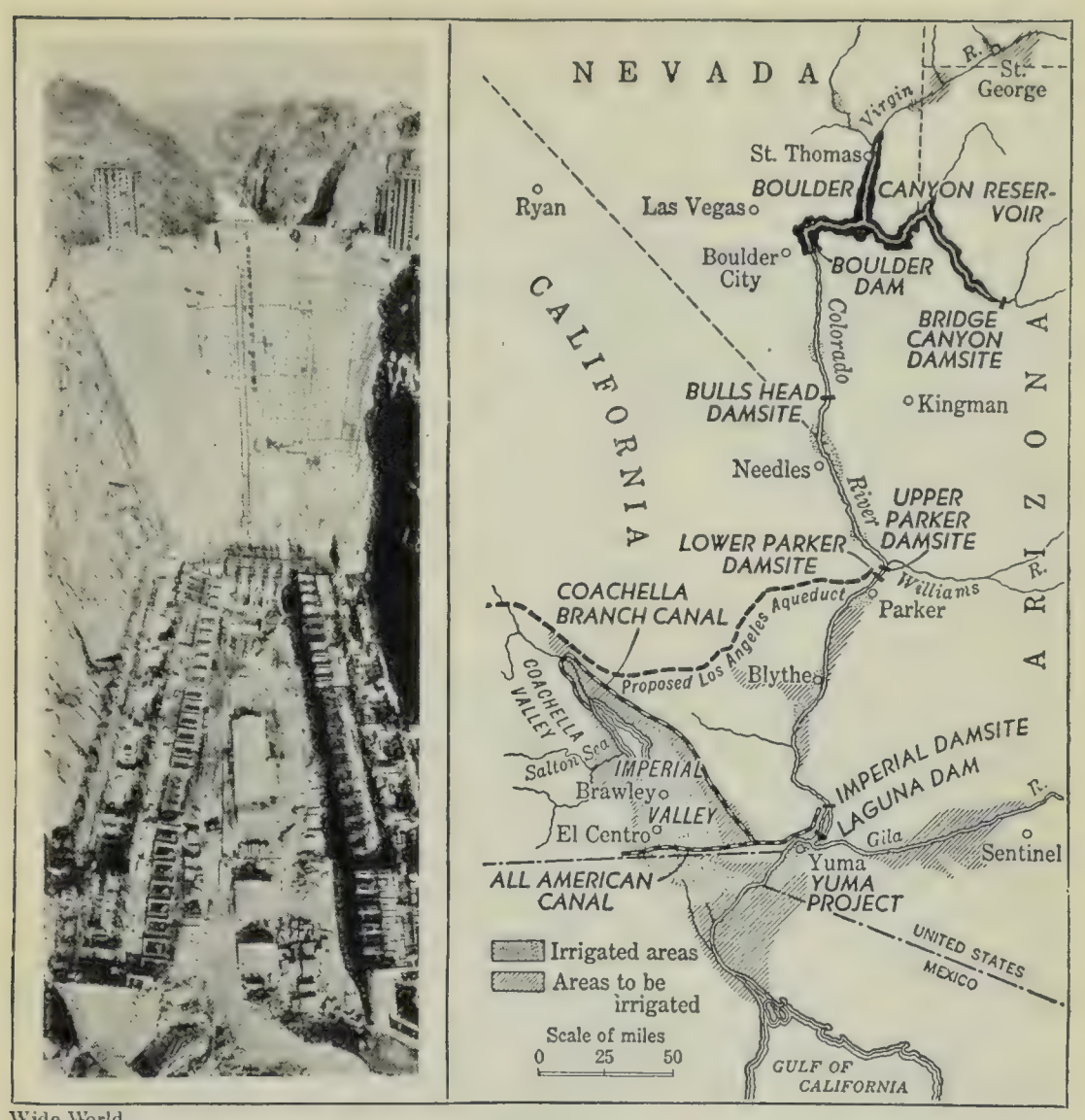
5. Grains grow best in the *mountains.*

6. Most of the harvesting in the United States and Canada is now done *by hand.*

Problem XXXVI–B · How is Farming Carried On in Regions where there is Little Rainfall?

Soils and water. Some kinds of swamp plants can grow in soils no matter how much water there is, and desert plants can grow with very small amounts of water. Most farm and garden plants cannot grow well in extremely wet or extremely dry soils. For this reason drainage ditches are used in the most successful farms and gardens.

Irrigated farms and gardens. There are many regions where the soil has all the qualities needed for producing crops with the one exception of water. In some of these regions crops are grown by irrigation and in others by dry farming. In irrigated regions deep wells from which water is pumped are sometimes used successfully. In certain sections great reservoirs into which the water



Wide World

FIG. 437. Photograph of Boulder Dam and map showing the location and the areas benefited by it. This dam, the highest in the world, makes possible the world's greatest artificial reservoir. It will supply water for Los Angeles, for irrigation purposes, and for developing electrical power. **Special Report:** Secure additional facts about Boulder Dam from the United States Department of the Interior

is pumped are placed in high locations. From these the water is allowed to run to the fields in either open or buried ditches.

***Irrigation projects.** The most extensive irrigation projects make use of rivers or mountain streams which are sometimes far away from the lands to be tilled. Valleys are made into immense lakes by the construction of enormous cement retaining walls (Fig. 437). These reservoirs are usually owned and managed by

A, James E. Wilson; *B*, Ewing Galloway

FIG. 438. *A*, Arizona irrigation canal; *B*, irrigating celery with water from an artesian well in Florida. What is the purpose of the parallel ditches in *B*?

companies, sometimes by state or national organizations. The water is delivered to the farmer through canals and is paid for like anything else he buys. Thus the mountain rains and snows, or even the water from glaciers, may be held in reservoirs and be used in crop production instead of running off directly to the oceans.

Irrigated regions. In Texas, California, Arizona, Colorado, Idaho, and some other states, irrigation is of the greatest importance. In fact, irrigation is profitable (Fig. 438) in any region with

a good climate and with an annual rainfall of less than twenty-five inches per year. If twenty-five inches of rainfall should be well distributed over the growing season, it would be sufficient for some kinds of crops. However, in dry regions evaporation is rapid. Therefore unless rainfall is abundant, well distributed, and well conserved, irrigation is necessary.

Soil water and humus. ***Experiment 115.*** What percentages of water and of organic matter are found in various kinds of soil? Bring to the laboratory several samples of soils secured from different regions. Try to secure samples of clay soil, sandy loam, gravel soil, and a loam rich in humus. Weigh equal volumes of all the different soils. Then dry the soils slowly, stirring them from time to time, taking care not to have heat enough to burn the organic matter. When the soil is dry, weigh the samples again. Then heat the samples hot enough to burn all organic matter, and weigh again. Calculate the percentages of moisture and of organic matter.

Exercise on scientific method (criticizing experimental procedures and using controls). What factors keep this experiment from giving absolutely accurate results? What are the controls in this experiment?

Crops of irrigated areas. Irrigation favors types of crops which respond to constant care, such as fruits, garden crops, sugar beets, and alfalfa. Wheat, corn, and other grains thrive under irrigation, but they can be produced more cheaply in regions of slightly less favorable climate and of naturally abundant rainfall.

***Irrigation and drainage.** When water is applied on the surface of the soil through irrigation, certain soil salts slowly collect on or near the surface and may prevent growth of crops. Hence, even in irrigated soils, drainage ditches are needed to carry away both these harmful salts and surplus[1] water.

Soil water and capillarity. An examination will show that any fertile soil is filled with extremely small cracks and capillaries (see Glossary). In these the soil water rises to the surface from deeper moist soil and is evaporated. So much of the soil water may thus be exhausted in dry regions that crops cannot be grown even though the soil is fertile. If the surface is well cultivated, however, the capillary passages in the surface layer are broken up and do not carry water to the surface. Tilling the surface,

[1] *Surplus* (sur'plus): the part that is extra or more than is needed.

therefore, conserves the water in the soil. In regions where irrigation is necessary a finely cultivated surface layer helps to retain the water that is put into the land.

Dry farming. In some dry regions of certain Western states not enough rain or snow falls each year to meet the yearly needs of farm and garden crops. Where irrigation is not possible in such places, a practice called dry farming has been introduced. The surface is tilled thoroughly, so that it is covered with a powdered soil or mulch. This mulch helps to prevent the evaporation of moisture. By going over the soil surface after a rain or whenever the soil begins to become hard, the surface is kept mellow and most of the moisture is held. The rainfall of two or more years may have to be thus conserved before there is sufficient soil water to grow a crop. Dry farming uses cheap lands, else it could not be successful. Such farming has not extended rapidly during recent years.

Self-test on Problem XXXVI–B. (*Do not write in the book.*) **1.** Most of the irrigation projects are carried on in the *Middle Western* states.

2. In the irrigation of farm land it is desirable to *leave on* the land the surplus water which does not sink into the soil.

3. The purpose of dry farming is to *add water to* the soil.

4. Soil water escapes to the surface chiefly by *osmosis*.

5. *More* water will evaporate from soil that is well cultivated than from uncultivated soil.

Problem XXXVI–C · How are Certain Plants and Animals Important to Farming and Gardening?

Agriculture and living things. The living things which help or harm crops include both plants and animals of numerous kinds. Some live in the soil, some live in or upon the plants, and the rest live aboveground. Many are microscopic. Much is known about some of these organisms, but little is yet known about others. Each is an interesting subject for scientific study, but only a few can be discussed here.

Some animals of the garden: 1. Insects. The insect friends of the garden are important. Bees, butterflies, and moths help the

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FIG. 439. Fighting insect pests with a dusting plane. **Self-test on Scientific Principles:** Can you explain how the fact that the parasitic larva of the ichneumon fly feeds on another larva which is a parasite on tomato plants illustrates the matter and energy cycles?

garden by carrying pollen from one flower to another as they go about gathering the nectar. The ladybird (Fig. 383, p. 567) feeds upon smaller insects, such as plant lice and scales, which are very destructive to young and tender plants. Ichneumon flies lay their eggs in the bodies of caterpillars of destructive kinds. The ichneumon-fly larvae feed upon their hosts, the tomato worms. Destructive insects are always to be feared as enemies of grain, vegetable, and lawn plants. When any one kind becomes abundant, specimens should be sent to the state agricultural experiment station with the request for advice as to what to do (Fig. 439).

2. Burrowing mammals. Moles, gophers, and gray squirrels damage farm and garden crops by burrowing in the fields and gardens and by eating the plants. They are fought with considerable success with traps. These traps should, however, be of types which kill the animals at once, thus preventing their suffering.

3. The earthworm. Possibly no single animal is more important than the earthworm in reducing material to such a condition

as to be useful to later plant growth. Earthworms swallow the soil in which there is organic matter. As they digest such parts of the soil as they can use they produce important changes which increase the fertility of the parts that they cannot digest. Moreover, the holes that they make in the ground to a depth of several feet permit air, water, and the roots of plants to enter.

4. Toads. Many people believe that toads are dangerous creatures and that handling them will give one warts. Such beliefs are absurd superstitions. The toad is a very valuable animal. Toads feed on insects and slugs. They hide under garden plants and close to them and destroy many of the pests which devour plants.

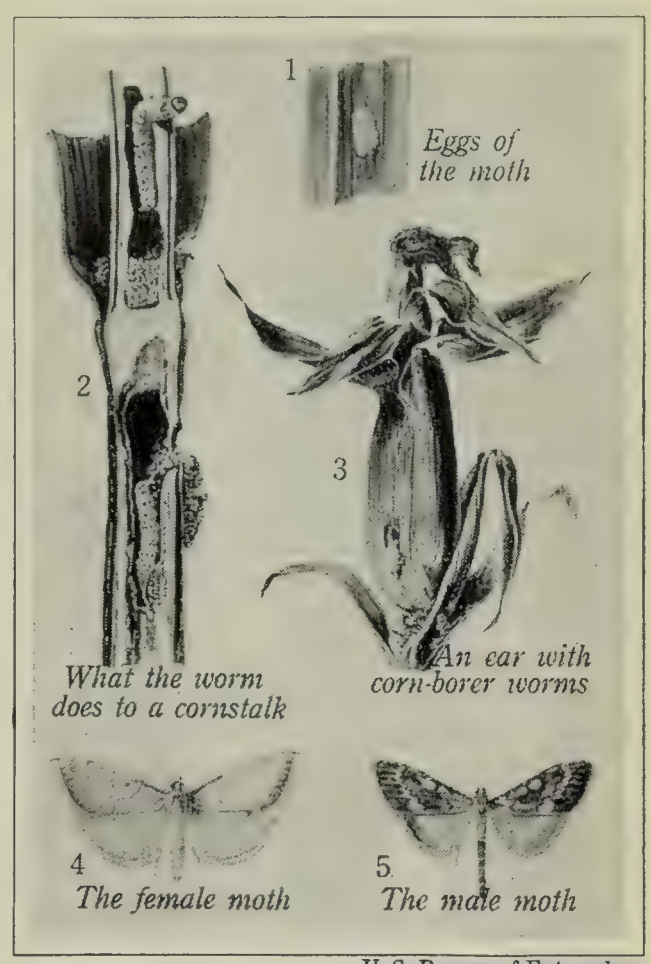
5. Snakes. Several varieties of snakes may live in the garden and be of great use in destroying harmful insects. Only a few of the numerous varieties of snakes are poisonous and therefore dangerous. Most of them are harmless. Besides insects, snakes eat mice and many other small animals which attack the crops. Snakes are often treated cruelly and are killed in great numbers by people who do not know them to be the valuable animals they are.

6. Birds. Much has already been said about the food of birds. The plantings suggested about the home will prove attractive nesting places for several kinds of birds. The constant presence of the birds and their care of their young will help to insure the successful growth of garden and lawn plants. Why?

Fighting plant foes. Molds, mildews, smuts, and rusts are fungi which attack several kinds of useful plants, such as wheat, oats, corn, potatoes, and fruit plants like the grape, apple, cherry, and peach. The spores of these fungi fall upon the host and immediately develop threadlike roots which force their way into the tissues of the host and absorb the sap. Some of these fungous parasites, for example the cherry and peach mildew, can be killed by spraying the plants with poisonous sprays.

Insect pests are numerous and attack many kinds of crop plants. Some larvae, like those of the tomato worm, the codling moth, and the potato beetle, eat the leaves of plants. The codling moth can best be controlled by spraying the apple trees with Bordeaux mixture just after the blossoms have fallen, for it is then that the female moth lays her eggs. Insects like the squash

bugs, which as adults suck the juices of the plants, may be killed by spraying the plants with fish-oil soap or kerosene. The potato-beetle larvae can be killed by spraying plants with arsenate of lead.



U. S. Bureau of Entomology

FIG. 440. Three of the four stages in the life history of the European corn borer. Which stage is not illustrated here?

***The Japanese beetle.** The Japanese beetle was first found in the United States at Riverton, New Jersey, in 1915. It has spread rapidly and widely. By the end of 1928 it was in Connecticut, New York, New Jersey, Pennsylvania, Maryland, and Delaware. It has since appeared in other states.

*The Japanese beetle is a successful animal; that is, it is well fitted to live in its environment and to multiply rapidly. Its young live in the ground upon the roots of many kinds of plants. The adult, or full-grown, beetle can live on the stems, leaves, flowers, fruits, and seeds of many kinds of plants. This insect has a longer adult life than most insects; hence it can do more damage by its longer period of eating. It has a few known natural enemies, as some birds and certain flies and wasps, but these have not yet been able to stop its advance. The United States government has voted large sums of money to study this beetle, to find and encourage its enemies, and to establish quarantine [1] in the effort to prevent its extension.

[1] *Quarantine* (kwor'an tene): a law for keeping disease germs or small pests from being carried to places that do not yet have them.

The European corn borer. The European corn borer (Fig. 440) is an insect recently introduced into the United States. In 1909 and 1910 it came as a most unwelcome guest in some broom corn which was shipped from Italy and Hungary into this country. The insect got started in three centers, from which it has been spreading so rapidly as already to have covered most of the Eastern and Middle Western states.

*The damage done by the corn borer is very large. In Ontario alone over twelve thousand square miles of the corn crop was completely destroyed in one year. The United States and Canadian governments and the state and provincial governments have voted many millions of dollars to stop this damage. The European corn borer can live on at least two hundred twenty-five different kinds of plants. Therefore when corn fails it for a time it can eat something else until there is another supply of corn.

Bacteria and soils. ***Experiment 116.*** Do some kinds of soil bacteria help plants to grow? Secure two pots of soil from a field in which good crops of clover or beans are growing or have recently been growing. Heat the soil of one pot to 130° F. and keep it at that temperature for twenty minutes; then plant in each pot some seeds of clover and beans. Keep both pots well watered and in a good growing light and temperature. When the young plants are a month old, what difference can you determine in growth and in root conditions? Explain.

Different kinds of animals, bacteria, and fungi may one after another do their particular parts in changing organic matter into simpler compounds. These simpler compounds can be dissolved in the soil water and taken up by the roots of green plants to be used again in the food cycle.

*Among the compounds most needed by green plants are those of nitrogen. Such compounds are produced through decomposition and decay. One group of soil bacteria changes the proportion of oxygen in these nitrogen compounds so that plants can use the compounds. Other soil bacteria, however, change those nitrogen compounds into others which plants cannot use, thus doing harm equal to the good done by the first group. Some kinds of bacteria may live in the smaller roots of such plants (legumes) as clover, sweet clover, alfalfa, beans, and peas. When these bacteria gain

entrance within the plant roots, the tissue of the roots enlarges about the bacteria and produces growths called nodules[1] (Fig. 441). The bacteria within these nodules secure nourishment from the plant roots, but they also combine nitrogen from the air of the soil with oxygen in a form which can be used by the plants. The plants help the bacteria by furnishing a home and food. The bacteria help the plants by providing a supply of nitrogen compounds which the host plants can use. The nitrogen compounds not used by the host plants remain in the soil, where they are used by the later crops of other plants. Thus because of the activity of these bacteria a crop of clover, beans, or peas leaves the soil more fertile than before the crop was planted.

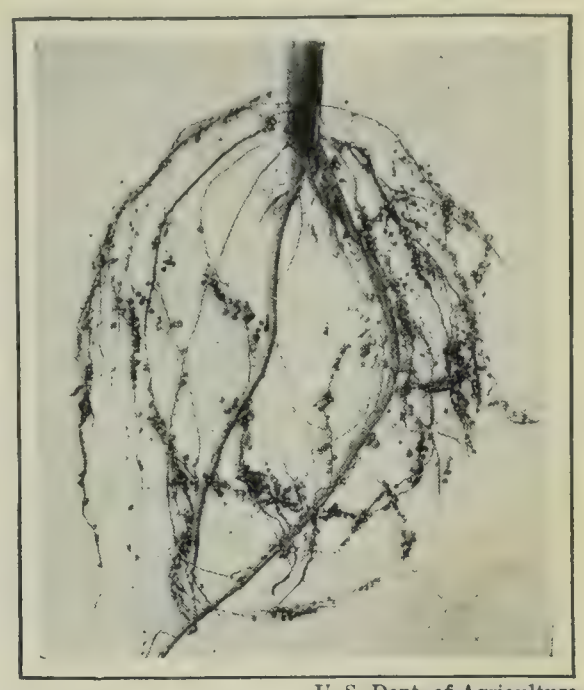


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FIG. 441. Roots of the soy bean with bacterial nodules. **Special Report:** When two organisms live together, each by its life activities making it easier for the other to survive, such a partnership is known as symbiosis. Secure from textbooks of biology and from an encyclopedia other examples of symbiosis

Rotation of crops. Farmers often use this knowledge of the activities of soil bacteria to maintain the yield of grain crops. After corn, wheat, or other grains have been planted in the same fields for several years in succession, the soil becomes poor in compounds of nitrogen because grain crops remove these compounds from the soil. To restore the nitrogen compounds to the soil, the farmers plant alfalfa, vetch, or clover in the fields for one year in every three or four. Often, moreover, instead of harvesting these crops, they plow them under in order to add humus to the soil. Then for several successive years they plant grain crops, until the soil has again lost so much of its nitrogen content that another planting of legumes is necessary.

[1] *Nodule* (nod'ule): an enlarged joint, small knot, or lump.

Self-test on Problem XXXVI–C. (*Do not write in the book.*) In the following list select those organisms which are helpful to crop-raising and those which are harmful to it:

1. molds
2. bees
3. gophers
4. gray squirrels
5. ladybirds
6. squash bugs
7. butterflies
8. mildews
9. rusts
10. toads
11. smuts
12. snakes
13. angleworms
14. birds
15. Japanese beetles
16. nodule bacteria
17. corn borers
18. codling moths
19. tomato worms
20. ichneumon flies
21. moles

Self-test on Scientific Principles. 1. Can you illustrate this principle: "Living things are engaged in a constant struggle for the available food energy"?

2. How would you illustrate with materials in this chapter, to a boy or girl of your own age who has never studied science, this scientific principle: "Certain organisms are helped and certain organisms are harmed by the life activities of other organisms"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is the soil enriched by plowing under any available plant refuse?

2. Why is valley soil likely to contain more humus than mountain soil?

3. Why will crop plants not grow in desert soil without irrigation even though the soil is fertile?

4. The adult codling moth is not a parasite on the apple tree, but its larvae are. Explain.

5. Is the European corn borer a parasite on the corn in any of its stages? in all its stages? Justify your answers.

Exercise on Scientific Attitudes. The French peasants have a belief, which comes down to them from the days of Rome, that they can protect their cabbages from cabbage worms by putting the shell of a hen's egg on the top of a stick stuck into the ground among the cabbages. They believe that the white eggshell attracts the butterflies and that these lay their eggs on the shell instead of on the cabbages. The butterfly eggs then dry out in the sunshine, or, if they hatch, the young cabbage worms die for want of food. Fabre, the great French scientist, once asked a group of peasants whether they had ever seen any eggs that had been laid by butterflies on the eggshells, or whether they had ever seen any

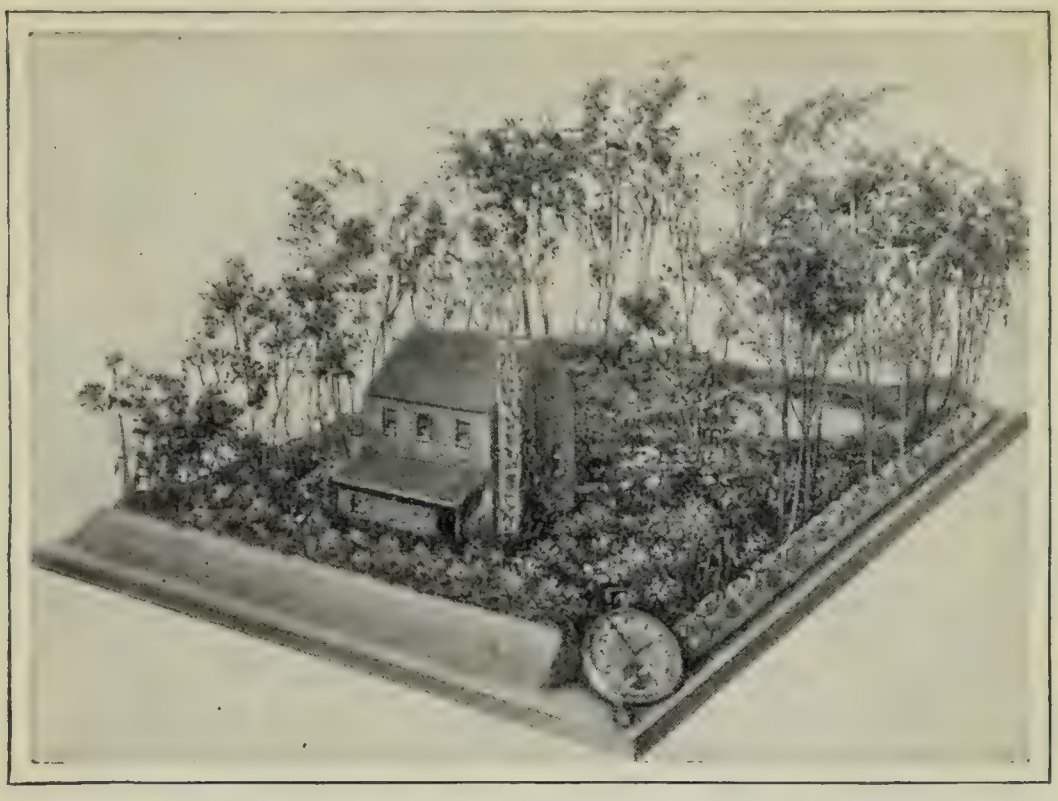


FIG. 442. This landscape plan was designed by two girls in a general-science class. The house and the fence walls were made of modeling clay. Pebbles were stuck into the chimney and the fence walls. The yard is of sand painted green by sprinkling thin paint over it. Hedges of dried moss run beside winding paths in the yard. The pool is a small mirror. The trees by the fence are dried goldenrod stalks. There is a rock garden. Can you design a landscape or garden plan? The watch was used in the picture to give an idea of the relative size of the landscape. How well does this plan agree with the suggestions for making a landscape garden, given on pages 663 and 664?

cabbage worms on the shells. They shook their heads. "Then why do this?" he asked. "It was done in the old days; so we go on doing it," they said. "That is all we know about it, but that is enough for us."

Which of the scientific attitudes (see pages 12–13) are illustrated here?

Exercises on Scientific Method. 1. Inventing Experiments. Can you plan an experiment to show the effects of keeping the top soil well cultivated?

2. Inventing Hypotheses. How many reasons can you suggest which might explain the rapid spread of the Japanese beetle?

Projects. 1. To make the best plan for either a vegetable garden, a home landscape planting plan, or a combination landscape plan and vegetable garden. Decide the amount of space to be used and the form. Make a diagram placing the buildings to be included, the walks and

drives, and the location and kinds of planting for the whole space. The different plans should be placed on the class bulletin board and discussed in class so that the best points in all the plans may be understood. After your plan has been discussed and improved by the class, make a model of your landscape garden, using modeling clay for buildings and walls, sand for driveways, colored sponges for trees, and so on (Fig. 442). Paint your model in suitable colors.

2. To study the life history of the toad. The life history of the toad is a very interesting one. A female toad lays nearly ten thousand eggs in long strings in the water. Soon the eggs hatch into tadpoles, which feed on algae and other organic matter. They breathe with gills, like a fish, using the oxygen which is dissolved in the water. The tadpoles grow hind legs, then forelegs. Finally the tail is absorbed and the toad comes out of the water, an air-breathing animal, which lives the rest of its life on land. It completes its development from egg to toad during a summer.

In early spring secure some toad eggs. Place them in a jar or aquarium with some pond weeds and watch their development from day to day. Keep a chart showing the dates upon which you first noted each important change.

3. To find the effect of cultivation on a crop of lettuce. Plant two lettuce beds with rows of lettuce six inches apart. Have all the conditions in both beds as nearly alike as possible. Cultivate the soil in one bed every other day for two weeks, beginning as soon as the lettuce plants first appear. Be sure not only to keep the soil mellow but also to remove the weeds from this bed. Do not cultivate the other bed. Describe the results.

Special Report. Study one of the chief harmful plant parasites of your community, such as rust on wheat, oats, or barley; smut on corn; potato blight; dodder on clover and alfalfa. Secure bulletins from agricultural experiment stations and prepare a report stating how the parasite lives and what may be done to prevent damage by it.

Books for Reference

Farmers' Bulletins on Gardening, Nos. 154, 218, 255 and 4.
Hodge, C. F. Nature Study and Life. Ginn and Company, Boston.

Chapter XXXVII Trees and Forests

Questions this Chapter Answers

Why have our native forests decreased so greatly in extent?
What values are derived from forests?
What are the chief causes of forest fires?
How are shade trees cared for?
How are deciduous and evergreen trees transplanted?
How may the forests be restored?
Of what interest and value are memorial trees?

Problem XXXVII–A · What are Some Important Values of Trees and Forests?

***The fate of our forests.** In early times in this country there were very large areas of both deciduous[1] and evergreen[2] forests (Fig. 443). As the trees were crowded together and had to reach for light, their stems had grown tall and straight and thus were of the best kind for making lumber. Almost half the land of the United States, or an estimated area of 822,000,000 acres, was originally covered by forests. There are now about 138,000,000 acres of native forests. When farming began, there was greater need to use the land for farms than for the timber. Much of this valuable timber, therefore, had to be burned. The destruction went so far that the original forests were almost all used for lumber or were burned. Lumber is now shipped across the United States from the forests of the Pacific Northwest to supply at least part of the needs of regions which have wasted and destroyed their own rich supplies of the finest forests.

Values of forests for lumber. Almost every person needs wood for something. Large quantities of lumber are constantly used in the construction of buildings, in making furniture and various farm and household implements, and in numerous other ways.

[1] *Deciduous* (de sid'u us): falling off when mature, as the leaves of certain trees. A deciduous tree is one that loses its leaves in the fall.

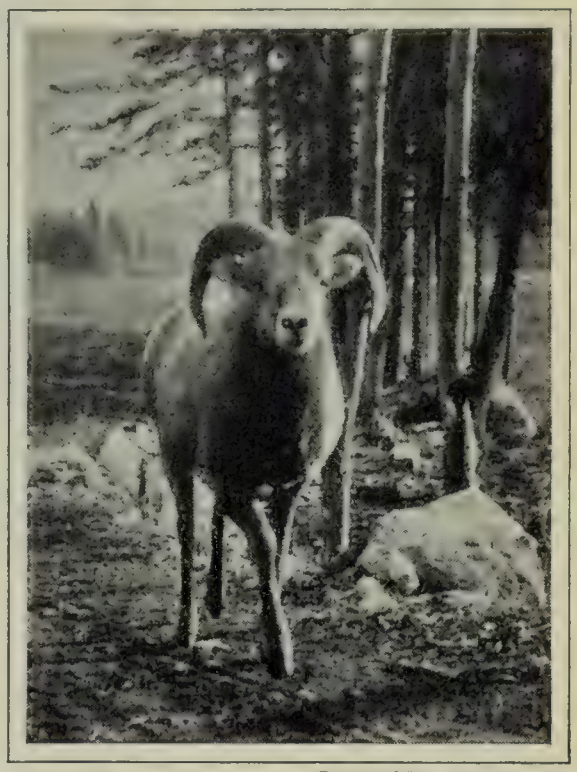
[2] *Evergreen* (ev'er green): a tree which keeps part of its leaves throughout the year.

FIG. 443. *A*, evergreen trees (white spruce); *B*, deciduous trees (two elms, left, and one sugar maple). Can you tell the season of the year from *B*? Can you explain what advantages the evergreen trees derive from their cone shape? How do you account for the fact that some of the branches of the sugar maple tree have turned away from the elm?

Over three hundred feet of lumber for each person are used in the United States each year. It seems likely that we shall always need timber. Forests are sources of many valuable products other than lumber, namely, fuel, wood pulp, resin, turpentine, rubber, camphor, and various kinds of fruits and nuts.

Other values of forests. Trees have many values other than as a source of lumber. They add to the beauty of homes and landscapes. They serve as homes for birds, and birds help to hold in check insects that would injure not only the trees but farm and garden crops. Forests provide places of recreation where we can study wild plants and animals in their native habitats (Fig. 444). Trees are important as soil-makers, both because their roots break up rock and soil, exposing them to the weathering action of the air, and because the leaves and twigs of trees fall and produce a spongelike mass which as it decays produces humus. The

humus absorbs and holds moisture in the soil. Since snows and rains are held by forests, the water runs off less rapidly than from open fields, and floods are less likely. This regulating of moisture also helps to reduce to some extent the extremes of temperature. Anyone who has been in dense forests knows that they are warmer in winter and cooler in summer than the surrounding open country. Explain why this is so.



Dept. of Interior, Canada

FIG. 444. Rocky Mountain sheep, Banff National Park, Canada. Plants and animals are protected in the national parks. **Special Report:** The national parks of the United States and Canada. Secure bulletins from the United States National Park Service, Washington, D.C., and from the Department of the Interior, Ottawa, Canada

Forests and flood control. Fig. 445 shows how forests are related to flood control. The larger part of the area drained by this river was once covered by forests. Most of it has now been cleared of forests. Other regions once covered by forests have been swept by great fires, which destroyed not only the trees but the humus as well. And so when heavy rains fall or snows melt, on either the cleared regions or the burned regions the water runs off rapidly. The lower part of the river receives in a few days or a few weeks much of the water which would have come down over a period of several weeks or even months if the upper parts of the area drained by the river had still had their original forests.

Trees may be planted in places where erosion of soils has been going on. If the trees get well started, their roots, and later their leaves, help to stop the erosion. The best kinds of trees to plant in such places are willows, cottonwoods, and black locusts. When the ground is not being eroded too rapidly, other kinds of trees,

FIG. 445. The Mississippi River drainage area. What kind of forests are chiefly found in this region?

such as ash, maple, walnut, oak, and hickory, which may later be more valuable for timber, may be planted to decrease the erosion.

Other means of flood control. Reforestation and care of the forests still remaining should help somewhat in controlling floods, but probably cannot prevent some future floods. The nation whose people have destroyed so much of the forests must now devote large sums of money toward preventing floods. The only immediate relief seems to be in building larger and better levees, in dredging the stream beds, and in providing certain valleys into which the water may overflow in time of floods. Thus, in addition to helping to control floods, the river basins and valley may be made to serve more effectively as reservoirs supplying water for irrigation, power, and other purposes.

Self-test on Problem XXXVII–A. (*Do not write in the book.*) 1. State five values derived from forests.

2. The original forests were destroyed chiefly by __(?)__ and __(?)__.

3. The best kinds of trees to use in preventing erosion are (1) __(?)__, (2) __(?)__, (3) __(?)__, (4) __(?)__, and (5) __(?)__.

U.S. Forest Service

FIG. 446. A forest fire and its results. How many means of preventing such destruction can you name?

Problem XXXVII–B · How are Trees and Forests Used and Conserved?

***Protection of forest trees.** In forests the chief danger to trees is from fires (Fig. 446). Forest fires are sometimes started by lightning. More often, however, they are caused by careless people who leave camp fires burning and who throw lighted cigars, cigarettes, or pipe tobacco and matches in places where fires may start. If such people could always be made to look at the fires they cause, to help fight them, and to repay, as far as they are able, those who suffer losses from them, there would be fewer forest fires.

Care of shade trees. Shade trees are attacked by many kinds of insects. If, however, birds are encouraged to nest in the trees, they pay their way not only by song and beauty but also by devouring the insects. In cities the trees are sprayed with insect poisons. This practice helps to hold the insects in check. If it were possible to have birds enough to control the insects, it would not be necessary to use poisonous sprays to fight insects.

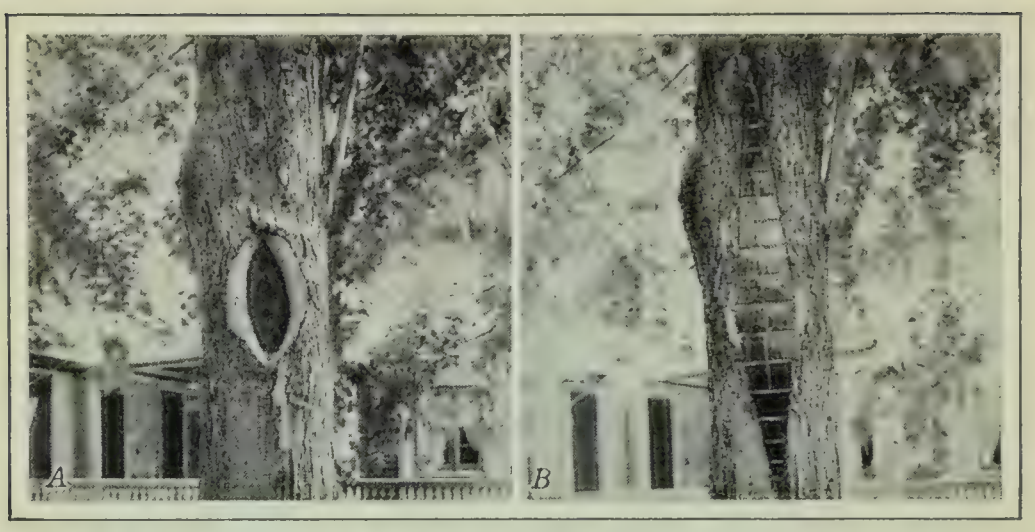


FIG. 447. *A*, an injured tree; *B*, the same tree after treatment. What reasons can you give why such treatment is effective?

Shade trees should be pruned to remove all dead limbs and to keep the trees in proper form. Even trees which have begun to decay may be pruned, the decayed places carefully cleaned by removing decayed and decaying wood, and the holes filled with cement, which is later painted over (Fig. 447). Thus the sources of further danger to the tree are removed.

Planting trees. Trees for planting are now usually secured from tree nurseries. In transplanting trees the sudden change usually makes less difference to the stem and the leaves than to the roots. The roots must secure water and other materials for the work of stem and leaves. Hence disturbing the roots must affect the whole plant. It is not often possible to remove all the roots without injury. When the tree is transplanted, therefore, the roots must become adjusted and must produce new root hairs before they can work well again. If water is not coming into the plant through the roots in the amounts needed and is being evaporated from the upper parts of the plant, there is danger of too much drying and of the death of the plant.

Transplanting deciduous trees. Deciduous trees when transplanted can have part of their branches pruned, that is, cut off, thus reducing the amount of the plant which the roots must supply with moisture. By the time new top branches and leaves have developed, the roots may have become well started and thus be

able to provide sufficient moisture for the whole plant. This pruning should also be so done as to help produce a good form for the plant. A densely planted forest may prune itself. The struggle to get light causes the trees to grow tall and straight, and the shading of lower limbs causes them to die. Later these dead lower limbs fall off.

Transplanting evergreen trees. Usually young evergreen trees are removed from the ground by carefully digging entirely round the roots. Then the roots, with the soil about them, are lifted into a tub of very wet clay. The clay sticks to the roots and soil. The whole mass is then rolled and tied in rough cloth. The cloth holds the roots and soil and keeps them moist for a long time. This method of treatment makes it possible to transport such trees long distances for planting. Very young evergreens may be transplanted directly if the roots are not allowed to become dry. Since new growth comes on evergreen trees only at the ends of branches, such trees cannot be pruned as can deciduous trees.

***How to arrange trees.** Trees planted for production of forests for timber should be spaced from six to eight feet apart. This soon causes them to crowd one another and to reach upward for light. In a few years such plantings have become dense growth, the stems have become straight, and the lower branches have begun to die and drop off from lack of light. After several years trees may be removed. The spaces may be replanted[1] or left for the spreading of older trees.

When planted for shade or decoration, each tree should be given plenty of space in which to produce a spreading top without becoming too high, for trees grow tall only when they must do so in order to secure light. Most cities now have laws prescribing where and how trees may be planted, and in many cities certain officials are responsible for such care as the trees may receive.

***Restoring the forests.** In the United States there are hundreds of thousands of acres of former forest lands now without trees and not good for cultivation. In many parts of the country, particularly in New England, in upper New York, in the states about the Great Lakes, and in some of the Southern states, lands which

[1] *Replant* (re plant′): to plant again or in the same place.

U. S. Forest Service

FIG. 448. *A*, an evergreen forest replanting itself; *B*, an evergreen tree nursery. Contrast the conditions under which the young trees in these two pictures are growing. Is there evidence of self-pruning in *A*? Explain. What is the relation between self-pruning and photosynthesis?

were once cultivated have been deserted by farmers. In time all these areas except those from which the soil has been eroded will again be covered with trees by natural seeding, but this is too slow a process (Fig. 448). In order that future generations may have forests for their needs and pleasures, a practical policy of reforestation must be maintained. Wherever old trees are used in the forests, young trees must be planted to take their places. Bare areas must be extensively planted with young forest trees. Through the United States Forest Service and the activities of the Civilian Conservation Corps much of this work is now being done.

Memorial trees. Trees have long served to mark historic spots and to call to memory historic events or the deeds of important men. Thus, in central Indiana a white-oak stump still stands as part of the former giant tree under which the church services of an entire community were held more than a century ago. In Coles County, Illinois, a black locust tree and an immense lilac bush mark the site of the first Illinois home of Abraham Lincoln. In Cambridge, Massachusetts, fenced within a small space between busy modern streets, there was lately an elm tree (Fig. 449)

under which, on July 3, 1775, General George Washington accepted the command of the armies of the Revolution. In the "big tree" forest near Santa Cruz, California, is the tree under which it is said the white people and Indians of California held their final peace conference.

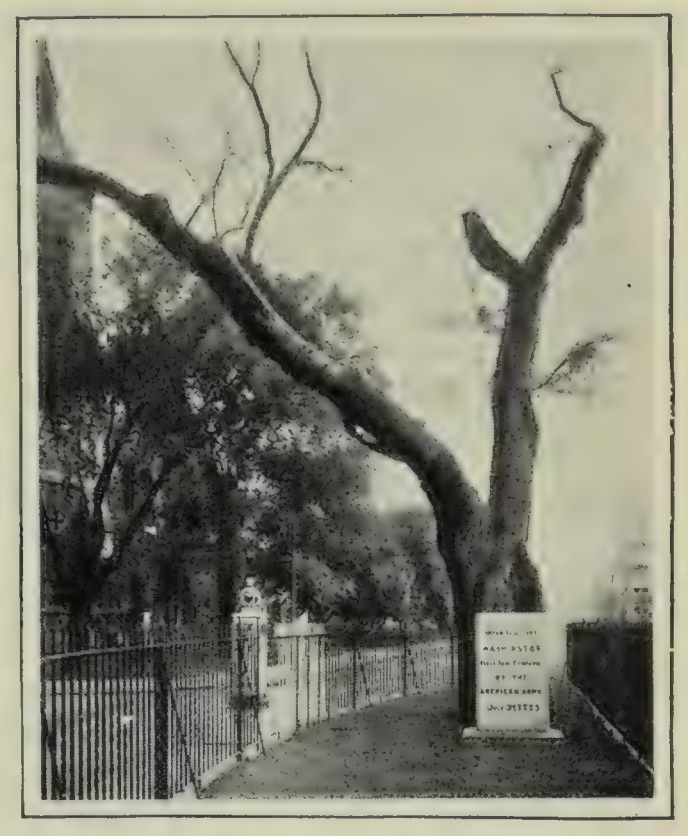


FIG. 449. The Washington Elm. The last of this tree fell in 1923. Special Reports: The memorial trees of your vicinity. The memorial trees of Sequoia National Park, California. (Consult the bulletin issued by the United States National Park Service)

Many thousands of trees have been planted and named for those who lost their lives in the World War. Sometimes the city has done this planting of memorial trees, sometimes it is done by special organizations, and sometimes it is done by the families and friends of those who are so remembered. It is peculiarly fitting that a long-lived growing tree should be made a monument to those whose acts still live, though they themselves are gone.

Many years ago a special tree-planting day was established called Arbor Day. Its purpose is not only to plant trees but to discuss the place of trees and forests in the pleasures and work of people. Organizations such as the Boy Scouts and the Girl Scouts have adopted programs of study and of action which have greatly increased public knowledge about trees and the general desire to plant them and care for them.

Self-test on Problem XXXVII–B. (*Do not write in the book.*) **1.** The chief enemy of the forest is __(?)__.

2. In the transplanting of *evergreens* some of the branches should be pruned off to reduce *osmosis*.

3. Trees produce better timber if they are planted *far apart.*

4. Forests should be conserved (1) by cutting no more trees; (2) by planting young trees as the old trees are cut; (3) by cutting very few trees; (4) by cutting all standing timber and then planting young trees in the area from which the timber has been removed; (5) by making laws forbidding the use of all lumber for building purposes.

5. More forest fires are caused by *lightning* than by *people.*

6. Planting trees is an effective means of reducing the amount of *weathering* of the soil.

ADDITIONAL EXERCISES AND ACTIVITIES

Project. To plant a tree. The hole for the tree should be made deeper than the tree is to be placed and be partly filled with soft earth and humus. If humus is not available, barnyard manure should be thoroughly mixed with the soil below the position to be occupied by the roots. Place the young tree in position with the roots carefully spread in all directions (Fig. 450). Sift soft earth over and among the roots until they are well covered. Press the soil gently but firmly with the hands, pushing slightly toward the stem as well as downward so as not to pull or break the roots. Then water the roots thoroughly and place more soft soil above them. The whole mass of roots should stand a few inches deeper than in the plant's old home. If dry weather should follow, keep the trees well watered, thus making the roots able to get moisture while they are becoming established in their new habitat.

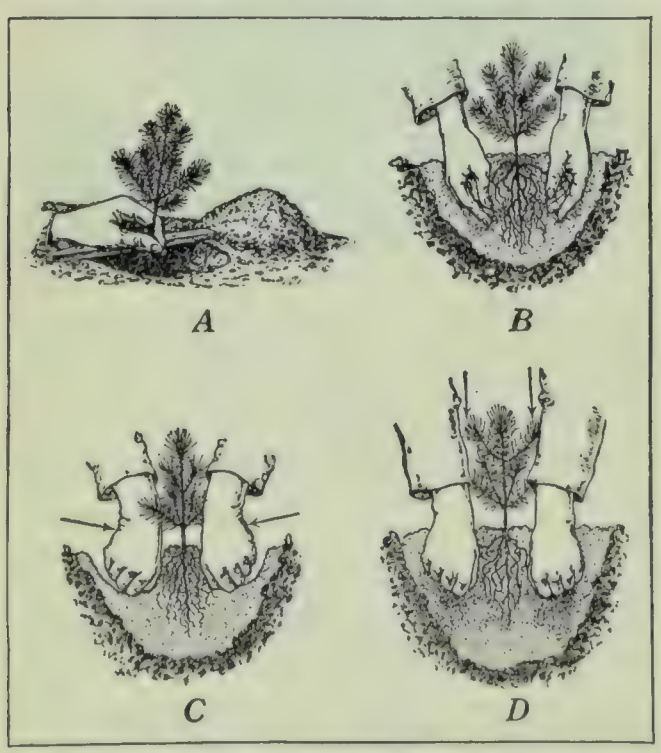


FIG. 450. Stages in proper tree planting. **Special Report:** Secure from your state or provincial forestry office bulletins describing what your state or province is doing toward reforesting areas that once had forests or toward developing new forest areas

Exercises on Scientific Attitudes. 1. The boys and girls were talking together before the meeting of the science club.

"I'll tell you what, there wouldn't be much science if it hadn't been for the Americans," said John. "Look at Edison, and Burbank, and Bell, and Fulton, and a lot of others."

"There have been just as great scientists from other nations," Frank objected. "I'm just as proud to be an American as you are, but we've got to give the other nations credit, too."

"Other nations have had some good scientists, maybe, but not as great as ours," John persisted. "You can't name as many that were."

"Maybe I can't, because I don't know much about them. But that doesn't prove I'm wrong."

"I just read in a magazine that Americans lead the world in inventions. So there's the proof that John is right," said Tom. "It was in print; so it must be so." Tom and John looked triumphantly at Frank.

"I heard Mr. Hoyt say that if it had not been for the Arabs, the torch of science would have gone out during the Dark Ages. I guess that means that the Arabs must have had some good scientists," said Sarah.

"The Arabs! How could they have great scientists?" said John, scornfully.

Several other members of the group now joined in the discussion. Some agreed with John and some with Frank and Sarah. The argument became noisier and noisier, but nobody seemed able to convince anybody else.

What scientific attitudes (pp. 12–13) did different members of the group possess, and which did they lack?

2. A newspaper article, under the heading "Rat Shows Pity," stated that a man had observed two rats running slowly alongside each other, both holding the same stick in their mouths. Upon closer observation the man had discovered that one rat was blind and that the other was carefully leading it along with the stick.

Do you think the conclusion in the heading is justified? Support your decision by quoting one or more of the scientific attitudes.

Question for Debate. *Resolved*, That man is harmed more by bacteria than by insects.

Books for Reference

Forestry Almanac. American Tree Association, Ithaca, New York.

Pack, C. L. School Book of Forestry. American Tree Association, Ithaca, New York.

Yard, R. S. Book of National Parks. Charles Scribner's Sons, New York.

UNIT XV · *Science for Leisure Time*[1]

PROBLEMS DISCUSSED IN THIS UNIT

The preceding fourteen units have presented materials necessary for general knowledge of the facts, laws, and principles of science and of their importance and values. You may have gained a scientific background which you can now use in studying and understanding other aspects and uses of science wherever you may find them. This unit directs attention to the use of science for further pleasure and recreation. It describes a number of scientific pastimes, hobbies, and recreational activities. It is not intended to be studied, as you have studied the preceding units. It is planned as a source to which you may turn for ideas and directions for making the most of your free time. The suggestions are similar in nature to the experiments, projects, and activities that are found throughout the first fourteen units. Most of those, however, are intended to be used in school, either in the classroom and the laboratory, in the science club, or in the school assembly. The activities described here are intended to serve for recreation during the out-of-school hours, both out of doors and indoors. The problems presented in this unit are these:

How can scientific knowledge be used in out-of-door pastimes?
How can scientific knowledge be used in indoor pastimes?

[1] TO THE TEACHER. Most teachers will have called attention of pupils to this unit early in the science course. By this means many pupils will have used such of the suggestions during the school year as has been made possible by their free time and interests.

Chapter XXXVIII · How Leisure Time may be Used for Increasing One's Knowledge and Enjoyment of Science

Problem XXXVIII–A · How can Scientific Knowledge be Used in Out-of-Door Pastimes?

A science diary. Many people keep diaries in which they write accounts of their activities from day to day. Some keep diaries relating to certain interests and activities, such as gardens, birds, baseball, or

Fig. 451. A good fishing place. What evidence of erosion is here?

airplanes. Some record accounts of the places to which they go, the people they see and with whom they talk, interesting happenings which they see, adventures, mishaps, and the like. A diary of this type is certain to be of interest, and is often of value, especially to the person who writes it. Its value and interest, however, can be greatly increased if it is planned to contain accounts of careful scientific observations of various sorts. Perhaps you can illustrate your diary with drawings or with photographs which you take (Fig. 451). Such a diary is sure later to be

a valuable source of materials for school work, such as compositions in English, special reports in the science classes, or talks at meetings of the science club. Here are five samples from the pages of a diary of this type:

Wednesday, July 7th. This afternoon we went surf fishing off the rocks during the flood tide. Mr. Haines showed us how to get some fine bait. We broke the barnacles on the rock with the back of a hatchet, and under the barnacles we found pink worms about five or six inches long. These were the bait we used for fishing. They could bite with jaws, which are somewhat like a beetle's. They couldn't hurt much, but it seemed bad because they were so ugly. But they were good bait. We got some rock cod and porgies and perch. I caught the biggest porgy of all, and when I cleaned it I found it full of little porgies. I had always thought that all fish laid eggs. I didn't know before that some fish produce their young alive like the higher animals.

Thursday, July 8th. I found a good agate stone near a shallow cave which was exposed at low tide. This cave seems to be hollowed out from just one layer of rock. I tried to scratch the back wall with my knife. It seemed as hard as the other layers of rock around it, but it must be a little softer or it would not have been worn away. Bill and I tried to think how long it must have taken to make that cave out of the rock, but we got dizzy trying to figure out the years it took the waves to do it.

Friday, July 9th. There is a large rock of sandstone just offshore with a good-sized spruce tree growing on it. We tried to figure out how that tree ever got started there. Bill said a squirrel must have carried the seed there, but how did the squirrel get there? Mr. Haines thought the seed might have been washed upon the rock by the waves. I thought maybe the wind had carried the spruce seed to the rock. The tree is stunted and twisted, but I wonder how it can manage even to exist there. We are all going to the lighthouse tomorrow.

Tuesday, July 14th. What an awful night! This idea of sleeping out of doors on the ground sounds fine, only there isn't much sleep. There was a root or a stone which dug into the small of my back every time I turned over. Bill said I shouldn't complain; he said he didn't have anything as soft as a boulder under him. I had lots of time during the night to study the constellations, and I noted several about which I mean to learn more. Before I go to bed tonight, I shall make a rough diagram of the sky, locating their positions. Then later I can look them up in a star book.

We all were ready to get up at daybreak. I never have seen such heavy dew as there was this morning. Jim and I got soaked as we walked down the trail to the beach. We wondered why the dew was so heavy. We supposed the reason was that the air was moister here by the ocean. Jim found a hermit crab in a shallow pool, and Mr. Haines photographed the crab later (Fig. 452).

Here are two samples from another kind of diary:

Wednesday, August 16th. Nothing of much interest happened today. We made 253 miles in spite of a puncture. We had it fixed while we ate supper

in De Witt. We drove a while longer after supper and saw one of the most beautiful sunsets I have ever seen. There was a distinct apple-green color along with all the other colors that sunsets usually have. I wonder whether green is a common color in sunsets over the prairie. None of us had ever seen green in a sunset before.

Newton H. Hartman

FIG. 452. A hermit crab. **Special Report:** Describe the characteristics and habits of the hermit crab

Sunday, August 20th. Today we crossed the great salt desert on the road from Salt Lake City to Reno. It was wonderful. The mirage is most interesting. It looked exactly as if we were near the shores of a lake or ocean, and I imagined I could actually see the waves rolling in on the shore. It is no wonder that travelers died of thirst while going toward such mirages as these. I am going to look up mirages in the physics book when I get home, and maybe I'll give a talk on them to the science club.

Mother took along a sandwich for little Tommy to eat during the morning. He dropped a piece of it butter side down on the seat and didn't pick it up, and mother sat on it. It got the car seat and her dress pretty well mussed, but later I got most of it off the car seat with a rag and some gasoline.

Star studies. Star studies are interesting to most people and are especially interesting to make during the warm evenings of summer. Fig. 453 and its legend explain how to make a star map showing how the constellations seem to move across the sky during the night as the earth rotates. Another interesting star-map project consists in making a series of star maps to show how the constellations and the stars change their positions as the season advances. For this make a star map as directed under Fig. 453, but make a new set of observations and a new star map either for every third night for a month or more or for one night each week for several months or a year. Make the observations at the same hour each night, and record the date and the hour.

Mount the whole series of maps on a big sheet of cardboard for a permanent exhibit for the science room at school. Find in an astronomy book the names of the most conspicuous stars and constellations on your charts. Then, in books about Greek myths, find some of the stories which the ancient Greeks invented to account for these constellations.

The study of an industry. There is no better way of using and increasing one's knowledge of science than by studying industries of various sorts. It does not matter what the industries are, whether farming, mining, shipping, smelting ore, logging, clothing manufacture, canning,

FIG. 453. Map of the heavens (modified from map by Hydrographic Office, United States Navy). This map shows a few of the more familiar constellations and a few of the "first magnitude," or brightest, stars. **Project:** To make a star map locating two constellations. Draw a circle with a six-inch diameter. Put a cross at the center. Label it "North Star." Write "North" at the bottom of the circle, "Overhead" at the top, "East" at the right, and "West" at the left. Early in the evening when the stars are showing, sight over a tree or the top of a chimney or house at the Big Dipper and at Cassiopeia. Carefully mark small crosses to show the exact positions of the stars in these constellations. Two hours later stand in the exact spot where you stood when you first marked the positions of these stars. Again note the positions of the stars in the two constellations. Have they moved? Mark their positions now with small circles. Write on your star map the exact hours and the date of your observations

making artificial ice, — any industries of your town or neighborhood will richly repay your study. You will find it desirable to collect your information in some orderly way, such as is suggested by this outline or by an outline you may make for your special study.

STUDY OF AN INDUSTRY

A. Raw materials used and source of each
  1. Sources
  2. Preparation
  3. Transportation
B. Sources of energy used in the industry
C. Processes carried on
  1. Machines
  2. Chemical processes
D. Finished products
E. A map showing sources of raw materials, and main regions to which finished products are sent
F. Valuable by-products
G. Waste products and their disposal
H. Reasons for locating the industry where it is

You can make your study of the industry of more value to you if you include as many applications as possible of the facts and principles of science that you have learned during your study of science. Such applications would include the following:

Tracing the transformations of energy which occur during the entire process. If biological materials are used, indicate the processes and the energy changes which produced the materials.

Analyzing the types of machines according to the purposes they are intended to serve (as explained on page 143 of this book) and according to the types of simple machines of which the compound machines are composed, so far as you are able to analyze them.

Listing as many principles of science as seem to you to apply especially to this particular industry.

Making collections. There are many kinds of science collections which high-school students can make with much profit, enjoyment, and increased knowledge. It is not enough, however, merely to collect certain kinds of specimens. With the collection there should always be an effort to find out the nature of the specimens collected. For this purpose you will need to study various "keys" which give such information. Also, the specimens collected should always be mounted in some appropriate way, in order that you may store and display them to the best advantage (Fig. 454). For the sake of those who may want to examine your collection it is well to prepare a booklet in which you describe your

FIG. 454. Two collections made by general-science students: *A*, rocks and minerals; *B*, birds' nests. Make a list of the kinds of collections you think you might like to make

specimens and give such information concerning them as you think would prove interesting and valuable. Visits to natural-history museums will give you many good ideas as to how to make and organize your own collections.

Diagramming the life of a given region. One interesting outdoor study is to map a small region and then indicate on the map the things that live on it. It is best to attempt to show but one kind of living thing. If your map is to show the animals of a region, it will be best to indicate the location of the living place, home or nest, of the animal by a check

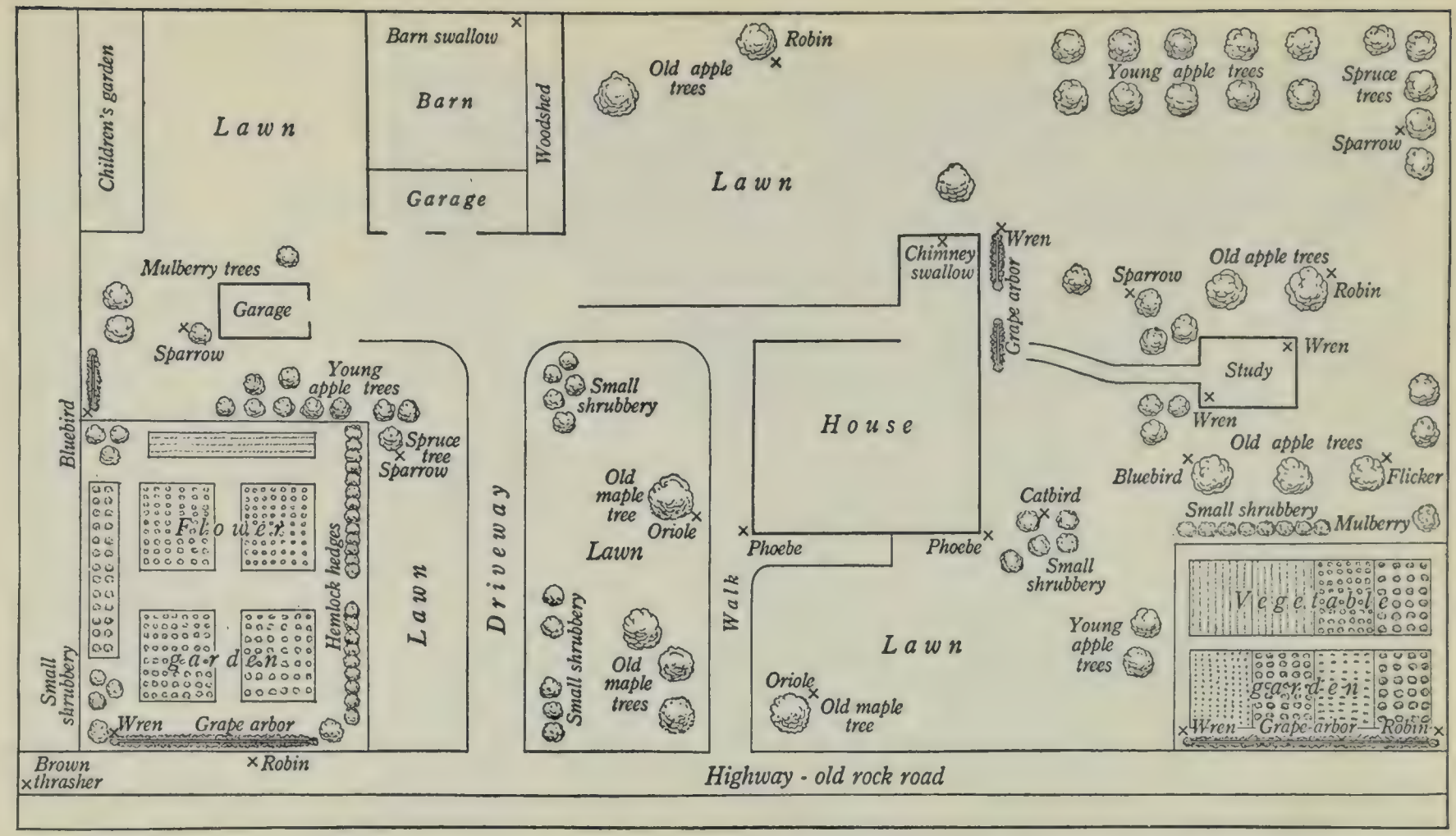


FIG. 455. Diagram showing the distribution of 24 birds' nests about a farm home in one season. The area of about 400 × 200 feet was particularly favorable to birds. Can you suggest the kinds of places in which birds can safely build their nests?

mark or number and then to write its name close to the mark. If there are many kinds of animals a separate list will serve best. For example, the spring and early-summer nesting of birds about one set of farm buildings (Fig. 455) provides valuable information about the relation of birds to the region in which they live.

Problem XXXVIII–B · How can Scientific Knowledge be Used in Indoor Pastimes?

Scrapbooks. A scrapbook is a pleasure to make and affords a rich store of materials for exhibits in the science room and for programs in the science club. The rotogravure sections of the newspapers, pictures in illustrated magazines, and advertising folders furnish a widely varied source of fine pictures (Fig. 456). Miscellaneous scrapbooks are not likely to be of great value. There needs to be a central theme for each, just as there needs to be a central theme for a good story or a good English composition. It is therefore best not to begin actual work on a scrapbook until you have collected considerable material bearing upon some one topic or phase of science. A good way to collect such material is to secure several large envelopes and to label each with the name of a topic which you want to study, as "Astronomy," "Wild Animals and their Habits," "Geology," "Unusual Machines and their Uses," "Aviation," "Native Trees," "Gardens," and the like. Put the good pictures and clippings you find into the proper envelopes until you get enough in one to make a good scrapbook. Have another envelope marked "Miscellaneous" in which you may place interesting pictures and materials which do not belong with any of the topics which you have selected for study but which may form the basis of other scrapbooks later.

A large scrapbook is usually better than a small one. Often a large advertising book may be used as the basis for making a scrapbook. Provide enough room to paste in the pictures and clippings without having to fold them. Also leave plenty of space between pictures and clippings for others which you may find later.

You will probably want to add sketches and diagrams of your own, or stories, specimens of materials and products, and the like.

Writing science dramas. The history of science as found in science textbooks, in encyclopedias, and in other sources is full of incidents which can be made into plays for use in the science classroom, in clubs, or in the school assembly. You will often find difficulty in getting accurate information concerning the details of the incidents. For example, the boy who wrote "The Discovery of the Telescope" which is given here said he could not be sure of all his facts because the encyclopedias which he consulted did not agree entirely with respect to how the telescope was

Union Pacific System

FIG. 456. Mount Rainier reflected in Mirror Lake, Mount Rainier National Park. An excellent illustration for a scrapbook on either "Light" or "Geology." What sort of legend should you make for this picture if you were using it to illustrate "Light"? "Geology"?

discovered; also the accounts of the Lippershey discovery merely said "children" and did not say how many or whether they were boys or girls. You will usually have to invent the conversation in most of your scenes. Make your stage directions as simple as possible.

Here are samples of the kinds of plays which pupils in general-science classes have written:

1. An Incident in the Work of Alexander Graham Bell

Scene: *A small booth in the building of the Department of Education at the Centennial Exposition in Philadelphia. (A small table with a chair behind it represents the booth; on the table is a telephone receiver, or something to represent it, and some wires leading from it.)*

Time: *Summer*, 1876.

Characters:

Alexander Graham Bell, inventor of the telephone
Dom Pedro, Emperor of Brazil
Empress Theresa, his wife
Several attendants
Judges of the exhibits: Joseph Henry, Sir William Thomson, and three others.

The scene opens with Bell *sitting behind the table. He rises as the judges approach.*

Bell. Good morning, gentlemen. You have been asked to come here today so that I may demonstrate my telephone to you. [*Offers receiver to nearest Judge.*]

Judge. Telephone? What does it do?

Bell. It enables you to carry on a conversation with another person who is some distance away.

[*Judges raise eyebrows, shake their heads, and otherwise show lack of interest and belief. One takes the receiver, idly examines it without interest, and lays it down without putting it to his ear. Another yawns, acts as if he were going to leave the room.*]

Judge. Well, I think we have seen all there is to see here. I think I shall go to my hotel.

Another Judge. I am going, too.

[*All act as if about to leave.*]

Enter Dom Pedro *with* Empress Theresa *and their followers (servants).*

Dom Pedro. Professor Bell, I am delighted to see you again. What is this? [*Picks up receiver.*]

Bell. It is a telephone receiver; hold it to your ear while I talk into the instrument at the other end of the room.

[*All wait while* Bell *crosses room.*]

Dom Pedro. [*With receiver at ear, shows great surprise.*] It talks! [*Acts as if greatly amazed.*]

Everybody: "What?" "Surely not." "That can't be possible," etc. [*Everybody now is interested and shows a wish to hear through receiver.*]

Joseph Henry. [*Takes receiver, holds it to his ear. A look of astonishment comes over his face.*] The emperor is right. It does talk.

Sir William Thomson. [*Holds receiver to ear.*] It does speak. It's dead material, but it does speak. It is the most wonderful thing I have seen in America!

[*Everybody exclaiming and taking turns with receiver as curtain falls.*]

2. The Discovery of the Telescope

Scene: *Spectacle-making shop of* Hans Lippershey *in Middelburg, Holland.*
Time: 1608.

Scene opens with Hans Lippershey *seated behind a table polishing a lens. Enter his children,* Hans, Jr., *and* Hilda. *The children approach table.*

Hans, Jr. Father, may we play with some of the pieces of glass you have been working with?

Hans, Sr. Yes, Hans, but you and Hilda play with them carefully and take care not to break or chip them. It takes a long time to polish one of them properly.

Both Children. We'll be careful, Father. [*Each takes two lenses and approaches window.*]

[*For a few moments the children look through lenses at each other, at their father, and at other objects inside the room and outside the house.* Hans, Jr., *holds a concave lens near his eye and a convex lens at arm's length and looks through window at the church spire. Suddenly he shouts in surprise.*]

Hans, Jr. [*With surprise*] Look, Hilda.

Hilda. What is it, Hans?

Hans, Jr. The church spire has come nearer. [*With increasing excitement*] Look, Hilda! Look, Father! When you look through the lenses this way, the church spire is bigger and closer.

Hilda. I don't believe it.

Hans, Jr. [*Still looking through the lenses*] But it's true. Here, take these lenses and see for yourself!

[Hilda *takes lenses but holds them awkwardly with the convex lens near her eye and the concave lens at arm's length.*]

Hans, Jr. No, not that way. You have the wrong lens near your eye. They have to change places.

[Hilda *follows his directions.*]

Hilda. I don't see anything.

Hans, Jr. [*Impatiently*] Move the lenses back and forth a little and you will! Here, like this! [*He takes hold of her hands and adjusts the lenses.*]

Hilda. [*With astonishment*] Oh, now I do! [*With increasing excitement*] Look, Father! Hans is right!

Hans, Sr. [*Looks up from his work.*] What is it, children?

Both Children. [*Excitedly*] Come here, Father, and see!

Hans, Sr. [*Slowly puts down his lenses and approaches the window.*] Let me see, Hilda, what you and Hans are talking about. [*Holds the lenses as* Hans, Jr., *did.*]

Hans, Sr. [*In great surprise*] Hm! My son, you have made a very great discovery. I can already think of many ways in which this which you have found by chance may be of great value to the world.

[*Continues to look through lenses and to adjust them in various ways as curtain falls.*]

FIG. 457. An aquarium. **Self-test on Scientific Principles:** Can you explain how a balanced aquarium illustrates the oxygen-carbon-dioxide cycle (see Index)? **Exercise on Scientific Method (Making Hypotheses):** Can you describe any conditions which might later develop in a balanced aquarium, any one of which might result in upsetting the balance?

Making a balanced aquarium. It is not easy to make a balanced aquarium, that is, one in which water plants and fish can live comfortably for several months without the need for changes of any sort in the aquarium meanwhile. It can, however, be done.

Secure a large glass vessel or tank a foot or more in each of its measurements. Place some pebbles and two or three inches of soil in the bottom. Fill it with tap or stream water to within six or eight inches from the top. Secure "waterweed" or "thousand-leaf," *Elodea*, *Cabomba*, or other water plants from an aquarium-supply store and place the plant in the water, with its roots in the soil. Place two small fish and a bullfrog tadpole in the water. If you put small tadpoles in the water, the fish will eat them. Add a few water-snails. These animals, like the tadpole, will eat the algae which would otherwise grow in such quantities on the inside surfaces of the glass vessel that they would obscure the view into the aquarium. Moreover, tadpoles and snails are good scavengers; that is, they feed on any sort of decaying animal or vegetable matter they can find.

After some hours have passed, watch the fish. If they come frequently to the surface and gasp, you will know that you have not enough water plants in the aquarium to furnish sufficient oxygen. If the plants cease

National Park Service

FIG. 458. *A*, part of the rim of Crater Lake, Crater Lake National Park, Oregon; *B*, antelope in Indian Gardens, Grand Canyon National Park, Arizona. **Special Reports:** Describe how Crater Lake was formed. Describe the nature and the habits of the antelope or other protected animal in any of the national parks of Canada or the United States

to thrive, you will know that there are too many of them in the water for the quantity of carbon dioxide supplied by the fish and the tadpole. By experimenting with the amount of growing plants and the number of living animals in the aquarium you may succeed in getting the proper balance of plant and animal life. Feed the fish only a small amount of food once a day, and remove from the water all the food they do not eat, so that it will not decay and pollute the water (Fig. 457).

Making a study of our national parks. You can secure from the National Parks Service of the Department of the Interior of the United States, at Washington, D.C., or of Canada, at Ottawa, Ontario, one or more interesting booklets on the different national parks. The railroad and the motor-bus companies and the travel bureaus likewise furnish booklets of information concerning the national parks. These booklets furnish a wealth of information concerning the location of the parks and their unusual features. There are several ways in which you can use this material. You can make a scrapbook showing interesting features of all the parks, or you can make a series of illustrated posters to display in class while you give a talk on one or more of the parks. You can write a "Tour of our National Parks," which will consist of a written account of the wonders to be found in each park, accompanied by illustrations from the booklets (Fig. 458). It will be interesting to make an outline map of the United States or of Canada, or of both, and to sketch on it an automobile route from your home to one or more of the parks, indicating the points of especial interest which one should visit on such a trip.

To make a radio receiving set which will enable you to hear stations a thousand miles away. *Materials:* The following materials will be needed (see illustration on the opposite page):

1 vacuum tube, type *ux* 199. (This is a dry-cell tube.)

1 four-pronged socket.

1 tuner, 3-coil, with a "tickler" coil that can be rotated. This vario-coupler can be made by winding 50 turns of wire on a cardboard cylinder 3.5 inches in diameter to serve for the secondary coil, 15 turns of wire for the primary coil, and 35 turns for the tickler.

1 variable tuning condenser, 23-plate. The plates of this condenser which can be rotated are called the *rotor* plates; the plates which cannot be rotated are called the *stator* plates.

1 mica fixed condenser, .0002-microfarad.

1 mica fixed grid condenser and grid-leak mounting, with 3-megohm grid leak to fit in the mounting.

3 dry cells.

1 set of headphones.

1 B battery, 22.5-volt.

2 dials, 4-inch.

1 lightning arrester; 1 ground clamp; 2 antenna insulators; 2 or 3 stand-off insulators; 4 pieces bus-bar wire 2 feet long; 1 piece "spaghetti" insulation; 5 Fahenstock clips; hard-rubber panel, $6'' \times 9''$; wooden baseboard; 100 feet No. 14 insulated copper wire for the aerial; 4-foot lamp cord for battery connections.

All these pieces of apparatus can be bought at a radio shop or an electrical shop for about $8.

Procedure: Mount the variable condenser and the 3-coil tuner on the back of the hard-rubber panel, thus: Drill two holes in the panel about equally distant from the middle, one for the shaft of the "tickler" coil on the mounting of the 3-coil tuner, and the other for the shaft of the variable condenser. Mount the 3-coil tuner on the right side of the panel and the variable condenser on the left side, as seen from the front. If more holes need to be drilled through the panel in order to fasten these instruments rigidly, follow the directions which come with the instruments. Now fasten the two 4-inch dials to the shafts of the 3-coil tuner and the variable condenser that project through the front of the panel (Fig. 460).

Screw the four-pronged tube socket to the baseboard at about the middle. Screw the five Fahenstock clips on the back and left sides of the wooden baseboard at the places indicated in Fig. 460 as $A-$, $A+$, $B+$, H, and I. Bus-bar wire should be used for all connections of the various pieces of the set (Fig. 460), and wherever possible these connections should be soldered to insure perfect contact. The bus-bar wire should be run

through the "spaghetti" insulation wherever there is possibility of its touching another wire. Why? Connect the two filament connections

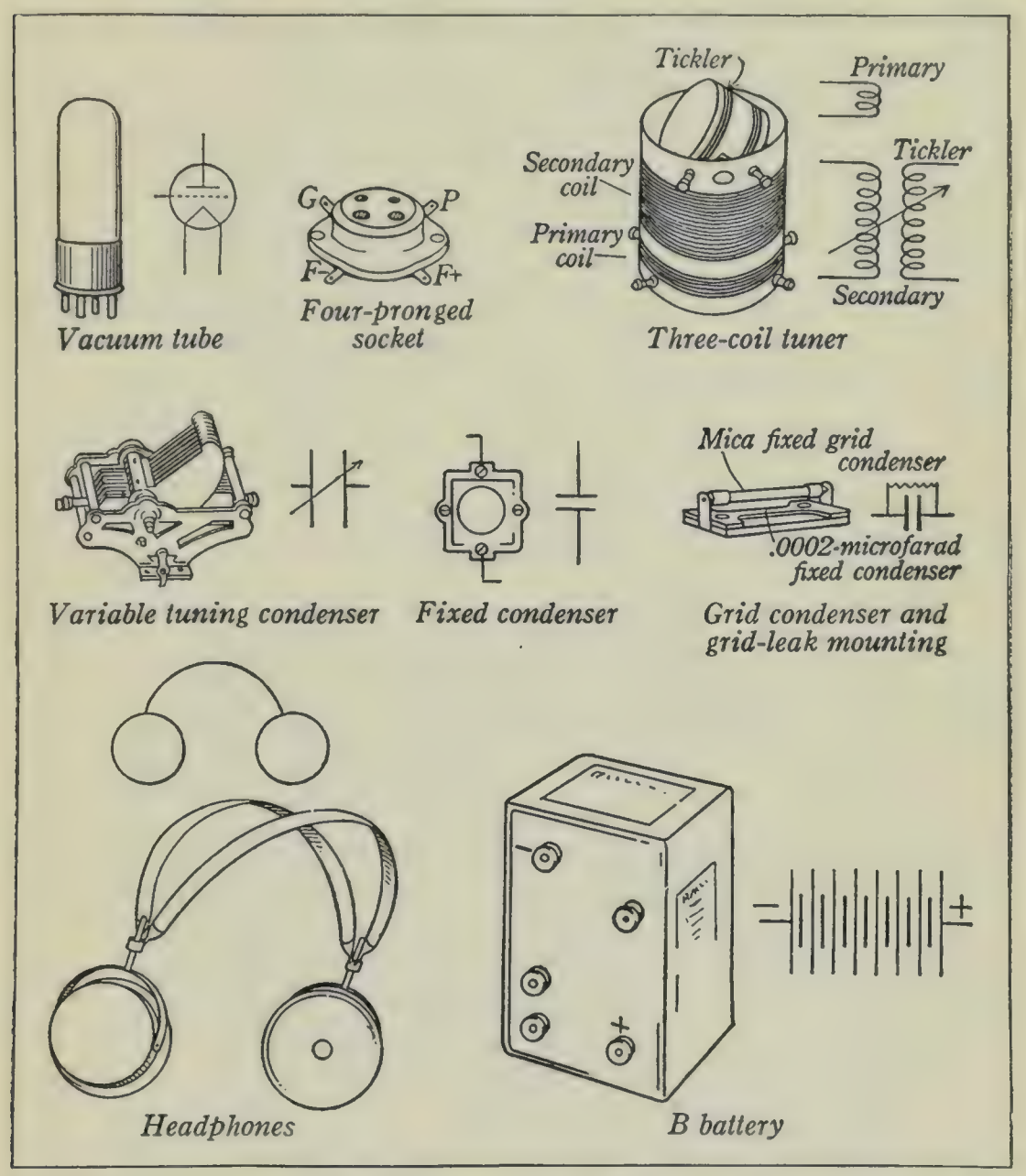


FIG. 459. Diagrams showing materials required for making a radio receiving set

of the tube socket, which are marked $F+$ and $F-$ respectively, to the two Fahenstock clips marked $A+$ and $A-$ (Fig. 460). Connect the $B+$ clip to H. Next connect to one terminal of the "tickler" coil (at the top) the plate connection marked P on the tube socket. Connect the other terminal of the "tickler" coil to the clip marked I (Fig. 460).

Fasten the small fixed grid condenser beside the tube socket (Fig. 460) and connect one end of the condenser to the grid clip which is marked G

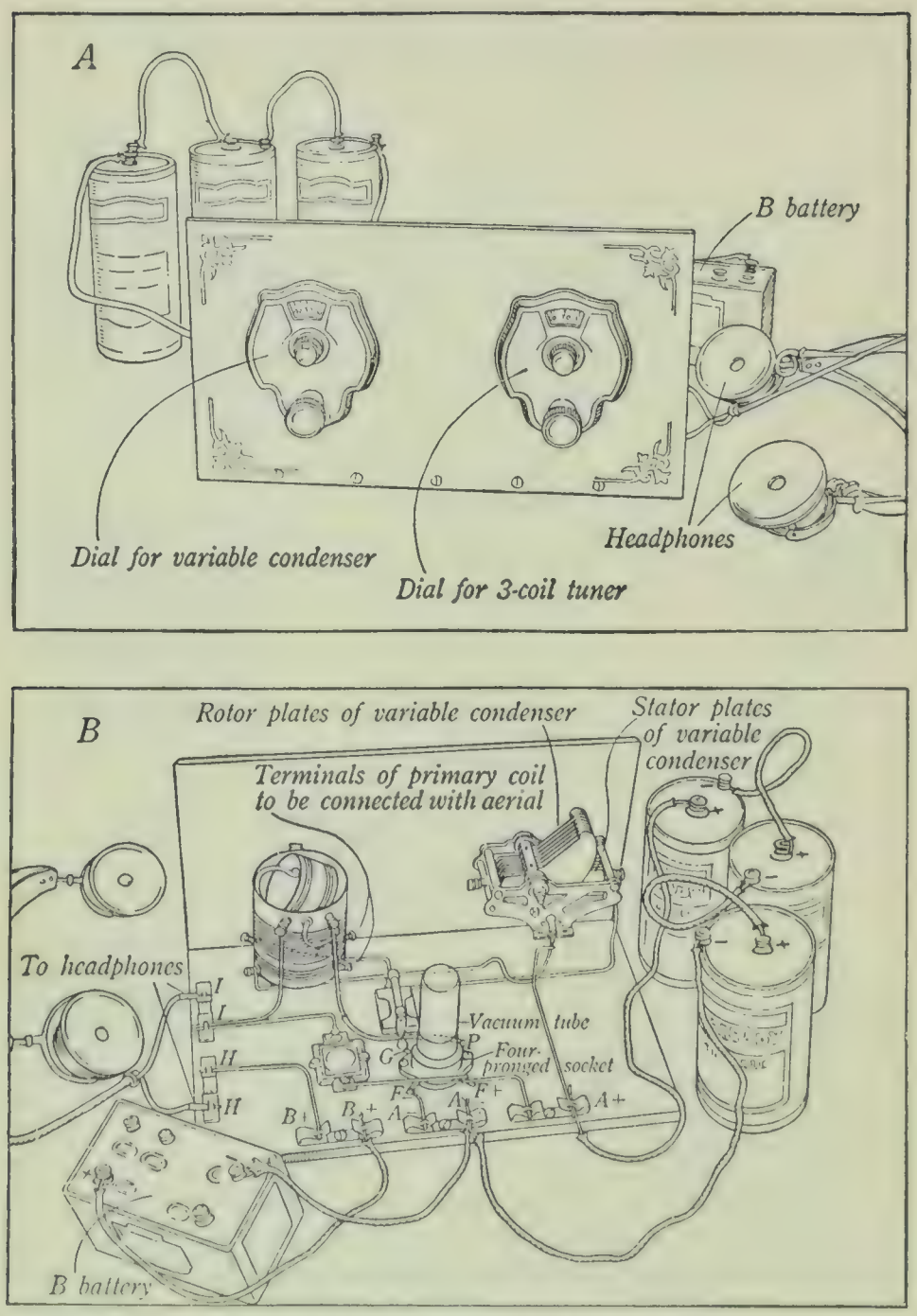


FIG. 460. Diagrams made from photographs of a radio receiving set constructed from these directions by two boys in a general-science class. *A*, front view; *B*, back view of assembled set. **Special Report: The invention of the practical radio by Marconi**

on the tube socket. In the set shown in Fig. 460 these connections are soldered together, no wire being used. Connect the other end of the grid condenser to the stator plates of the variable tuning condenser (Fig. 460). Also connect this same end of the small fixed grid condenser to the terminal of the 3-coil tuner which is connected with the upper end of the secondary coil. You will need to look at the tuner coil from the inside in order to be sure that you have the right terminal. Now connect the terminal from the lower end of the secondary coil to the *rotor* plates of the variable condenser. Note that in Fig. 460 spaghetti insulation is used on this wire. Connect the rotor plates of the variable condenser with either the $A-$ or the $A+$ clip (Fig. 460, *B*). After the whole set has been assembled, you will need to experiment to find out whether this last connection should be made with the $A-$ or the $A+$ in order to give best results.

Connect one terminal of the primary coil of the 3-coil tuner to the aerial. This consists of a wire about a hundred feet long suspended between two houses, or between a pole or tree and a house (Fig. 461, *B*), with a "lead-in" wire from it entering the house through a window or other convenient entrance point. Each end of the aerial must be insulated by using the antenna insulators. The "lead-in" wire must be soldered to the end of the aerial nearest the point of entrance. The "lead-in" wire must also be insulated from the house by means of the stand-off insulators. A lightning arrester must be inserted (Fig. 461, *B*), and the wire must be grounded.

The second terminal of the primary coil of the 3-coil tuner must be grounded; that is, a wire must lead from it either to the ground or to some metal which leads to the ground. A water pipe makes an excellent ground. Scrape the surface of the pipe bright and clean, then fasten the ground wire to it by means of the ground clamp. Fig. 461, *B*, shows the primary terminals, but the "lead-in" wire and the ground wire have been disconnected. After the set has been assembled, you may need to experiment in order to find out which terminal of the primary coil should be connected with the aerial and which should be grounded.

Fasten the .0002-microfarad mica condenser to the baseboard beside the tube socket. Connect one terminal of this condenser to the terminal of the tube socket marked $F+$ (Fig. 460), and connect the other end of this condenser to the clip marked *I*.

Now connect the three dry cells in series (see page 390) with the $A+$ and the $A-$ clips (Fig. 460). Plug in the tube. If the tube lights, connect the $+$ terminal of the *B* battery to the $B+$ clip and the $-$ terminal of the *B* battery to either the $A+$ or the $A-$ clip. If the tube does not light, try a new tube, or try new dry cells, and check all the connections to be sure they agree with the instructions and are tight. If

the apparatus is new and the connections are correct, the tube will light. Try both ways and leave the connection where it gives best results.

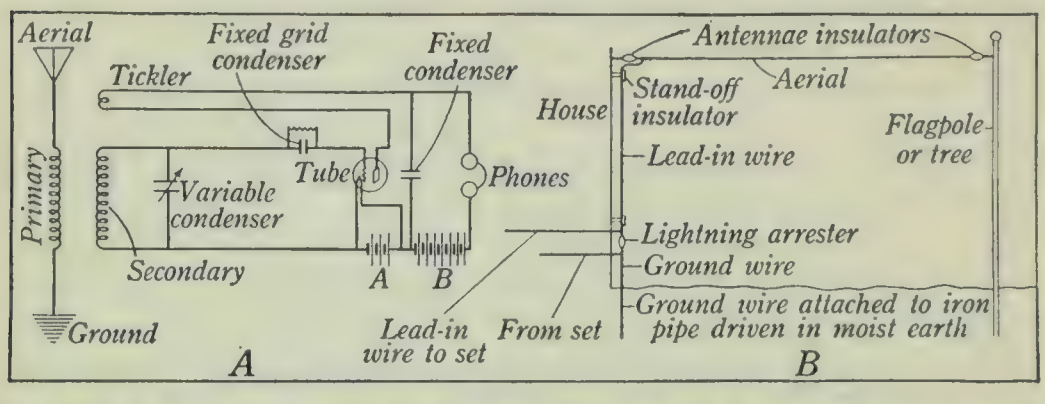


FIG. 461. *A*, the radio engineer's diagram of the set; *B*, diagram showing outside wiring for the homemade radio set. What safety devices are used in this diagram?

Sometimes better results are obtained if the $A+$ or the $A-$ connection is also grounded.

Connect the headphones to clips *H* and *I* (Fig. 460). The set is now completely assembled.

Adjust the headphones over your ears; rotate the "tickler" coil carefully by means of the right-hand knob on the front (Fig. 460, *A*) until a slight hiss is heard in the phones. Rotate the condenser dial (left-hand knob, Fig. 460, *A*) until you hear a whistle; then *carefully* rotate the "tickler" coil to the left or right until the whistle becomes faint. Rotate the condenser dial slightly to left or right and you will hear music or talking. To be sure that the set is working as well as possible, try out the various other connections suggested at several points in these directions.

With this set it will be possible during the summer to hear stations several hundred miles distant, though static may interfere with clear reception from distant stations. During clear winter weather it should be possible to hear stations a thousand miles distant.

To make a short-wave set capable of receiving stations over long distances. *Materials:* 1 vacuum tube, 30 or 01A.

2 four-pronged sockets.

6 four-pronged tube bases, taken from burned-out tubes.

2 used receiving-type variable condensers capable of having some of their plates removed. Leave only two rotor plates and three stator plates. The rotor plates are the ones that are movable. If new condensers are purchased, buy 50-microfarad midget condensers.

1 grid-leak condenser and mounting, .00025 or .0001 mfd.

1 grid leak, 3 to 10 megohms.

1 short-wave-type radio-frequency choke.

1 set of headphones.

1 rheostat, 20-ohm, for controlling filament temperatures.

1 B battery, 22.5 or 45 volts.

2 No. 6 dry cells if the tube used is type 30. If the tube is a 99, use three dry cells. Be sure not to turn up the rheostat too far if the tube is a 30, because it will easily burn out if more than 2 volts are connected across its filament. If a type 01A is used, a 6-volt storage battery will take the place of the dry cells.

The same dials, aerial, clips, etc. can be used in building this set that were used in the broadcast set described in the preceding radio project. Most of the parts can be taken from old battery sets or purchased for a few cents as secondhand parts.

Procedure: First take the variable condensers apart and remove enough plates to leave only two rotor plates and three stator plates. It would be well to double-space the plates, that is, to take out every other plate, if the set is to be used on the lower short-wave bands. It is desirable to fasten a copper or tin sheet to the back of the panel or to use a metal panel to remove "hand-capacity effects" in tuning. The metal sheet, in any case, should be connected to the ground post of the set.

The variable condensers should be mounted on the panel in the same manner as they were in Fig. 460. The rheostat should be mounted between them. One four-pronged socket (the coil socket) is screwed to the baseboard about an inch behind the rheostat, and the tube socket is mounted about an inch farther behind the coil socket.

The antenna condenser is made from two $\frac{1}{2}$-inch brass angle bars, one of which has a slot in the base so that it can be moved. The other angle is fastened securely to the baseboard. This condenser can be varied by adjusting the movable plate. This adjustment does not have to be made often, as it is merely a method of adjusting the antenna to the receiver.

The wiring of the set is next in this procedure. The wire used should be insulated and flexible, and the connections should be as short as possible and direct to the part. Some of the connections may have to be soldered, though for most of the parts screw connections are adequate. The plug-in coils are wound on four-pronged tube bases taken from burned-out tubes. First of all, the glass bulbs must be broken, and the glass and cement must be removed from the bakelite bases. It is desirable to have the bulb under a piece of paper or cloth when it is broken in order to prevent injury from broken glass. The cement can be removed from the bases with a knife after the bases have been placed in boiling water. The solder can be removed by heating the prongs of the tube bases with a soldering iron and then giving the bases a quick jerk

to throw out the melted solder. Holes for the wires to go through can be drilled in the sides of the tube bases with a small drill or with a sharpened shingle nail in a hand drill. The drawing of the tube-base coil should be carefully studied in order to insure an understanding of where the holes are to be drilled and how the coils are connected. If the coil is not correctly connected, the set will not operate. The filament prongs on the socket are the two large ones. When you are looking down on the top of the tube base with the filament prongs toward you the grid prong is the small one on the upper left-hand side of the tube base, and the plate prong is the small one on the upper right-hand side.

If the parts you are using differ from the ones used in building the set here described, the set may not operate. In that case add or subtract a few of the turns on the tickler coil until you succeed in getting the set to respond properly.

If reasonable care has been taken in constructing this set, you should be able to hear stations the first time you turn it on. To tune in, turn the regeneration-condenser dial until a faint rushing noise is heard. This is known as the point of oscillation, and the set is most sensitive at this point. Next turn the tuning dial. You will probably hear a code or broadcast-station carrier. It will be necessary to readjust the regeneration condenser as often as the tuning dial is readjusted. The rheostat is used to regulate the voltage and current of the tube filament. It should be turned as low as possible for satisfactory operation, and in no case should the tube have a greater filament current sent through it than that for which it was designed.

While this set will not operate a loud speaker, it will give comfortable volume on a pair of headphones, and amateur, police, aviation, television, commercial phone and telegraph, and foreign and American short-wave broadcast stations can be easily tuned in on it.

If the loud-speaker volume is desired, an audio transformer, a tube socket, and another tube are required. The transformer's primary (marked P and B) is connected in place of the headphones, and the secondary (marked G and F) is connected to the grid and F terminals on the tube socket. The filament wires are connected to the filament connections of the detector-tube socket. The plate terminal of the tube socket is connected to one tip of the headphones, and the other headphone tip is connected to the B of the B battery. The volume will be increased if an additional B battery is connected in series with the one used for the detector tube, but this is not necessary for thoroughly satisfactory operation.

If you are interested in learning more about short-wave radio, write to the American Radio Relay League of Hartford, Connecticut. They publish the *Radio Amateur's Handbook* (price $1.00) and *How to Be-*

come a Radio Amateur (price 25 cents). After you have built a short-wave set you will probably want to learn the code so that you can understand what the amateurs and commercial stations are saying. The code is not difficult to learn, and two or more students can practice together with a code-practice buzzer set during spare time. It is important to learn the code by the sound of the letters rather than by dots and dashes. When you think of a letter, don't think "dot-dash-dot" but "dit-dah-dit," which is more as the letters actually sound.

If you learn to send and receive the code at a rate of ten words a minute, and if you have learned some of the radio laws and how radio transmitters and receivers work, then you can take the examination for the amateur operator's license. This license costs nothing and is given by the Federal Communications Commission in most of the larger cities.

Amateur radio is a very interesting hobby, and you can talk to other boys and men all over the world. A ten-watt station can "talk" to amateurs in Australia or New Zealand or almost any part of the world if conditions are good.

Reading for pleasure. You have found at the ends of practically all the preceding chapters brief lists of "Books for Reference." The list of books which follows consists of those which are intended for entertainment as well as for instruction. It includes books of interesting stories; others which are accounts of adventure in the search for scientific knowledge; and others which show people's ideas regarding science. This brief list is made up of books that many boys and girls have found interesting. You will often find other scientific books by the same or by other authors which you may like even better. Your school or city library will usually contain one or more new books about science. Indeed, the public interest in science is so great that new scientific books are constantly being purchased.

BOND, A. RUSSELL. On the Battle Front of Engineering. Scientific American Publishing Co., New York.

Two boys have many exciting adventures while learning about some of the greatest feats of the engineers.

BOND, A. RUSSELL. Pick, Shovel and Pluck. Scientific American Publishing Co., New York.

Exciting stories and adventures having to do with the great works of the engineers, chiefly on, over, and under rivers.

BOND, A. RUSSELL. With the Men who Do Things. Scientific American Publishing Co., New York.

Exciting stories and adventures of two boys who wanted to learn about some of the great works which the engineers plan and carry out.

CALDWELL, OTIS W., and LUNDEEN, GERHARD E. Do You Believe It? Doubleday, Doran & Company, New York.

Interesting accounts of popular superstitions, how they got started, and evidence showing whether it is wise to believe them.

CHAPMAN, WILLIAM G. Green Timber Trails. D. Appleton-Century Company, New York.

Stories of animals of the big woods.

DE KRUIF, PAUL. Hunger Fighters. Harcourt, Brace and Company, New York.

An entertaining discussion of food and health problems; the romance of recent research regarding health.

DE KRUIF, PAUL. Microbe Hunters. Harcourt, Brace and Company, New York.

A well-written discussion of human relations to bacteria.

FABRE, JEAN HENRI. Insect Adventures. Dodd, Mead and Company, New York.

Uncle Paul tells the children many delightful stories of spiders, bees, wasps, and other insects.

FABRE, JEAN HENRI. The Wonder Book of Chemistry. D. Appleton-Century Company, New York.

A family of French children hear many interesting stories about chemistry from their scientist uncle, Uncle Paul.

GIBSON, CHARLES R. Chemistry and its Mysteries. Seeley, Service & Co., Ltd., London.

Stories of chemistry which you will enjoy reading about and knowing about.

GIBSON, CHARLES R. Romance of Scientific Discovery. Seeley, Service & Co., Ltd., London.

Scientific stories about all sorts of things from dinosaurs to planets.

HAWKSWORTH, HALLAM. The Strange Adventures of a Pebble. Charles Scribner's Sons, New York.

All sorts of strange and interesting things which scientists have learned from studying such things as rocks, mountains, and volcanoes.

JEWETT, FRANCES GULICK. The Next Generation. Ginn and Company, Boston.

An interesting book which tells how plants, animals, and human beings may be improved from generation to generation.

LEWIS, ISABEL M. Splendors of the Sky. Duffield & Green, New York.

Stories of the planets, the stars, the comets, and other heavenly bodies.

MCFEE, INEZ N. Secrets of the Stars. Thomas Y. Crowell Company, New York.

All sorts of scientific facts about the stars, the planets, and other heavenly bodies.

MILLS, ENOS A. Waiting in the Wilderness. Doubleday, Doran and Company, Inc., New York.

Stories you will enjoy about wild animals of the deep forest.

MIX, JENNIE I. Mighty Animals. American Book Company, New York.

About the dinosaurs and other strange creatures which lived on the earth many thousands of years ago.

PARKMAN, MARY R. Conquests of Invention. D. Appleton-Century Company, New York.

Stories of the great inventors and how they finally succeeded in making their great inventions.

PUTNAM, DAVID B. David Goes Voyaging. G. P. Putnam's Sons, New York.

An eleven-year-old boy tells his own experiences and adventures while on a scientific voyage with a great naturalist.

REED, W. M. The Earth for Sam. Harcourt, Brace and Company, New York.

An uncle explains to his nephew the story of mountains, rivers, dinosaurs, and men.

REED, W. M. The Stars for Sam. Harcourt, Brace and Company, New York.

An uncle tells Sam, his nephew, about the heavenly bodies.

ROLT-WHEELER, FRANCIS. The Boy with the U. S. Survey. Lothrop, Lee & Shepard Co., Boston.

Adventures of a boy with a party of scientists in the great Southwest, in and around the Grand Canyon, and in Alaska.

ROLT-WHEELER, FRANCIS. The Boy with the U. S. Weather Men. Lothrop, Lee & Shepard Co., Boston.

Many exciting adventures of boys on a flooded river, in a tornado, and elsewhere.

SCOVILLE, SAMUEL, JR. Everyday Adventures. Atlantic Monthly Press, Boston.

A family of boys and girls with their father have all sorts of pleasant adventures while studying the wild things near their home.

SLOSSON, E. E. Snapshots of Science. D. Appleton-Century Company, New York.

Many engaging short stories about all kinds of science topics.

TALBOT, FREDERICK A. All About Aircraft of Today. Funk & Wagnalls Company, New York.

Just what the name indicates — facts and stories about airplanes, dirigibles, and other aircraft.

GLOSSARY

The following scientific terms are important in the study of general science. A page number is given with each term. That is not the only place where the term is used, but is a page on which will be found an additional explanation which will be helpful. The wording of the definition in the Glossary usually differs somewhat from that in the text, but gives the same idea, and often an additional meaning or meanings. If after reading the definition in the Glossary you will turn to the page indicated and read the discussion there, you should then have a clear idea of the proper use of the word.

The Glossary serves not only as a convenient "dictionary" of important scientific terms which appear in the book but also as a useful means of review of many important topics discussed in the book.[1]

absorb (ab sorb′): to take in a liquid or other substance, as a blotter takes in ink (p. 93).

*[2] **acid** (as′id): a substance which turns blue litmus paper red (p. 111).

adhere (ad here′): to stick to, as a stamp *adheres* to an envelope (p. 124).

adhesion (ad he′zhun): the sticking together of different kinds of molecules (p. 124).

adulterant (a dul′ter ant): an impurity put into foods or other materials to reduce the cost of manufacture (p. 654).

***air**: the mixture of gases and dust which surrounds the solid earth (p. 17).

algae (al′je): a group which includes many of the simplest green plants (p. 545).

***alloy** (al loy′): a substance formed by melting together two or more metals (p. 354).

***alternating** (al′ter na ting) **current**: an electrical current which constantly reverses its direction through the circuit (p. 396).

***altitude** (al′ti tude): height above sea level (p. 23).

***ammonia** (a mo′ni a): a gas which acts as a base or alkali, made of the elements nitrogen and hydrogen (p. 28).

amoeba (a me′ba): an exceedingly small one-celled, jelly-like animal that lives in the water or upon moist soil (Fig. 408, p. 607).

***ampere** (am′peer): the unit of electrical current (p. 384).

Amphibia (am fib′i a): the group of animals, such as frogs and

[1] To the Teacher. Suggestions for the use of the Glossary will be found in the *Teachers' Manual.*

[2] The starred terms represent those topics which were considered essential in the study of general science by at least two thirds of the teachers of general science who indicated their judgments in the research investigation cited on page iii of the Preface.

toads, which in early life have gills and live in water, like fishes, and most of which when adult have lungs (p. 564).

*analysis (a nal'i sis): the process of studying a substance in order to determine the elements or compounds of which it is composed (p. 117).

*anatomy (a nat'o my): the study of details of structures of plants and animals (p. 602).

aneroid (an'er oid) barometer: a kind of barometer having a metal box, from which air has been removed, instead of a mercury column (Fig. 13, p. 25).

anesthetic (an es thet'ik): a substance which dulls the senses so that pain is not felt (p. 402).

anticyclone (an'ti si klone): a "high," or area of high barometric pressure, moving as a slowly whirling body of air across the country from west to east (p. 226).

antiseptic (an ti sep'tik): a substance that kills bacteria or prevents their growth, as tincture of iodine (p. 88).

antitoxin (an ti tox'in): a substance which is produced by a living animal or plant and which overcomes the effects of disease germs (p. 629).

armature (ar'ma chur): in a motor or dynamo, the coils of wire which rotate between the magnetic poles of the field and in which electrical current is generated (p. 396).

*artery (ar'ter y): one of the blood vessels through which the blood travels from the heart to the capillaries in all parts of the body (p. 603).

*artesian (ar te'zhan) well: a well bored into sloping layers of soil or rock saturated with water which is under pressure great enough to force the water to the surface of the ground (p. 75).

*assimilation (a sim i la'shun): the process of changing digested food into living protoplasm (p. 528).

asteroid (as'ter oid), or planetoid (plan'et oid): one of the group of small planet-like bodies which revolve round the sun in orbits which are between those of Mars and Jupiter (p. 279).

*astronomer (as tron'o mer): one who has a broad and exact knowledge of astronomy (p. 261).

*astronomy (as tron'o my): the science of the stars and other bodies in the heavens (p. 261).

*atmosphere (at'mos fear): the blanket, or layer, of gases surrounding the solid earth; the gaseous outside part of the earth (p. 18).

*atom (at'om): one of the parts making up a molecule (p. 112).

attitude (at'i tude): a fixed habit of action (p. 12).

*axis (ax'is): the imaginary line running through the earth from the north pole to the south pole (p. 306).

*bacteria (bak te'ri a): a group of very small plants which includes some of the germs which cause diseases (p. 85).

barograph (bar'o graf): a self-registering barometer of the aneroid type (p. 25).

***barometer** (ba rom'e ter): a device for measuring the pressure of the atmosphere (p. 22).

***base**: a substance that turns red litmus paper blue (p. 111).

bathysphere (bath'i sfeer): a globe from within which scientists study ocean life (p. 65).

battery (bat'er y): two or more electric cells joined together (Fig. 259, p. 389).

***beam**: a ray of light (p. 487).

***biology** (bi ol'o jy): the study of plants and animals and of the ways in which they secure, conserve, and use energy (p. 596).

blizzard (bliz'ard): a storm in which a strong cold wind is accompanied by snow or sleet (p. 230).

***blood**: the fluid within the bodies of animals which carries food materials to all the living cells and carries waste materials from the cells (p. 603).

***breathing** (breeth'ing): the process of taking air into the lungs and forcing it out again (p. 607).

caisson (ka'son): a large cylinder in which work is done under water (Fig. 30, p. 50).

***calcium** (kal'si um): a metal, one of the elements which make the common compound known as lime (p. 95).

***calorie** (kal'o ry): the quantity of heat energy which must be put into 1 gram of water to raise its temperature 1 degree centigrade. A Calorie, written with capital C, is 1000 calories (p. 169).

calyx (ka'lix): all the sepals of a flower taken together (Fig. 394, p. 584).

cambium (kam'bi um): the growing layer in a plant stem or branch (p. 540).

***capillarity** (kap i lar'i ty): the rising of a liquid into very small tubes or openings (p. 545).

***capillary** (kap'i la ry): fine, hairlike; one of the very small tubes through which the blood flows after leaving the arteries and before entering the veins (pp. 545 and 604).

***carbohydrate** (kar bo hi'drate): food, such as sugars and starches, consisting of carbon, hydrogen, and oxygen (p. 638).

***carbon dioxide** (di ox'ide): a colorless and odorless gas, a compound composed of the elements carbon and oxygen (p. 28).

caterpillar (kat'er pil er): the wormlike young of moths and butterflies (Fig. 386, p. 571).

***cell**: (biological) one of the very small units of protoplasm of which all living things are composed (p. 525); (electrical) a device for changing chemical energy into electrical energy (p. 386).

***centigrade** (sen'ti grade): on the scale of one hundred (p. 168).

***centrifugal** (sen trif'u gal) **force**: the tendency for all parts of a whirling body to move outward from the center (p. 121).

*character (kar'ak ter): one of the principal features, qualities, or characteristics of a living thing, as its color, size, form, or structure (p. 588).

*chemical (kem'i kl): having to do with chemistry (p. 11); a substance which acts upon other substances, changing them and itself into still other substances (p. 116).

*chemical change: a change of a substance into another substance having entirely different properties or characteristics (p. 116).

*chemist (kem'ist): a scientist who knows and uses chemistry (p. 11).

*chemistry (kem'is try): the study of substances for the purpose of finding what they are made of and how they act (p. 11).

*chlorophyll (klo'ro fil): the green coloring of plants (p. 541).

*circulation (sur ku la'shun): the process by which a gas or a liquid flows to all parts of a body (p. 602).

*circulatory (sur'ku la to ry) system: the system of vessels by means of which the blood of an animal or the sap of a plant is carried through all parts of the animal or the plant (p. 603).

*climate (kli'mat): the average of the weather conditions over a long period of time (p. 249).

*clotting (klot'ing): the process by which blood thickens when it is exposed to the air and hence stops the bleeding of wounds (p. 605).

cloud: a mass of very small drops of water formed by the condensing of water vapor in the air (p. 236).

cloudburst (kloud'burst): an extremely violent and heavy rainfall (p. 241).

coagulate (ko ag'u late): to become like a jelly or a half-solid substance (p. 605).

*coal: a fuel composed almost wholly of carbon (pp. 179, 346).

coal gas: a fuel made artificially by heating soft coal in airtight furnaces (p. 182).

cocoon (ko koon'): the shell or case in which insects of certain kinds live while developing from the larva, or wormlike stage, into the adult stage (p. 568).

cohesion (ko he'zhun): the sticking together of the same kind of molecules (p. 124).

cold: the condition which exists when there is no heat energy present (p. 166).

*combustible (kom bus'ti bl): able to burn, inflammable (p. 29).

*combustion (kom bus'chun): the act of burning or of oxidizing (p. 29).

*comet (kom'et): a heavenly body having a bright head and a less bright tail and following an orbit round the sun (p. 284).

commutator (kom'u ta tor): a "split ring" on a direct-current generator or motor which keeps the electrical current always flowing in the same direction through the external circuit (p. 396).

*__compass__ (kum′pas): an instrument for determining directions on the earth (p. 369).

*__compound__ (kom′pound): a substance composed of two or more chemical elements, or simple substances (p. 112).

*__compression__ (kom presh′un): the act of compressing or the state of being compressed (p. 47).

*__concave__ (kon′kave): curving like the inside of a ball; the opposite of convex (Fig. 326, p. 480).

__concave lens:__ a lens which has one or both surfaces curving and which is thinner in the middle than at the edges (p. 480).

*__condensation__ (kon den sa′shun): the changing from a vapor or a gas to a liquid or a solid (p. 61).

*__conduction__ (kon duk′shun): the method by which heat energy or electrical current (streams of electrons) passes through a substance such as a metal (p. 195).

__conductor__ (kon duk′tor): any substance through which heat energy passes readily by conduction (p. 195); any substance through which electrical currents pass readily (p. 383).

*__constellation__ (kon stel a′shun): a group of stars, as the Big Dipper (p. 263).

__contaminate__ (kon tam′i nate): to make dangerously unclean with disease germs; to pollute (p. 85)

__control:__ a control in an experiment is any part of the experiment which gives a basis for comparison of results or for checking the accuracy of results (p. 20).

*__convection__ (kon vek′shun): the method by which heat energy travels in water or air by means of currents (p. 194).

*__convex__ (kon′vex): curving like the outside of a ball; the opposite of concave (Fig. 326, p. 480).

__convex lens:__ a lens which has one or both surfaces curving and which is thicker in the middle than at the edges (p. 480).

__corolla__ (ko rol′a): all the petals of a flower taken together (Fig. 394, p. 584).

*__corpuscle__ (kor′pusl): a very small body, such as a cell in the blood (p. 603).

*__crater__ (kra′ter): a chimney-like opening in a volcano from which come melted rock, ashes, or gases, or all of these (p. 290).

__crystal__ (kris′tal): a specimen of mineral having a characteristic number of flat sides which meet at a point (p. 357).

__cyclone__ (si′klone): a "low," or area of low barometric pressure, moving as a slowly whirling body of air across the country from west to east (p. 227).

__cytoplasm__ (si′to plazm): the watery part of the protoplasm of a living cell (p. 526).

*__decay__ (de kay′): the process by which bacteria and other simple organisms reduce the dead bodies of plants and animals to simple compounds and elements (p. 554).

__deciduous__ (de sid′u us): shedding all the leaves at regular times (p. 677).

***decompose** (de kom poze′): to break down a substance into simpler substances by means of heat or decay (p. 348).

***density** (den′si ty): the number of pounds which a cubic foot of a substance weighs, or the number of grams which a cubic centimeter of a substance weighs (p. 122).

dew point: the temperature at which water vapor in the air first begins to be condensed as dew, frost, or fog (p. 231).

***diaphragm** (di′a fram): a thin vibrating disk or membrane (p. 428).

diastrophism (di as′tro fizm): the warping and twisting of the earth's surface as the materials of the earth are shifted under the pull of gravity (p. 325).

***diffusion** (di fu′zhun): the reflecting of light in all directions from a rough surface (p. 460); the slow mixing of gases by the movements of the molecules of the gases (p. 527).

***digestion** (di jes′chun): the process by which foods are changed to liquids that can be used by the body (p. 606).

dinosaur (di′no saur): a reptile, often of enormous size, which lived ages ago and has long since disappeared (Fig. 241, p. 359).

***disease** (di zeez′): any condition within the body of a plant or an animal which results in injury to the plant or the animal (p. 623).

disinfectant (dis in fek′tant): a substance, as chloride of lime, that kills disease germs or prevents their growth (p. 88).

***dissolve** (di zolv′): to distribute the molecules or exceedingly small particles of a solid or a gas among the molecules of a liquid (p. 59).

***distillation** (dis ti la′shun): the act of boiling a liquid and then condensing its vapor (p. 62).

doldrums (dol′drumz): a wide area on both sides of the equator where the air currents rise vertically and hence will not drive sailing vessels (p. 251).

dormancy (dor′man sy): a condition of prolonged quiet and lack of action; state of being dormant (p. 533).

***drainage** (drain′aj): the flowing or draining of water from higher to lower levels; also the liquids which so drain (p. 86).

***dynamo** (di′na mo): an electrical generator; a machine for transforming mechanical energy into electrical energy (p. 394).

***eclipse** (e klips′): the shutting off of the sun's light from the earth by the passage of the moon between the sun and the earth; or the shutting off of the sun's light from the moon when the moon passes into the shadow of the earth (p. 296).

***efficiency** (e fish′en sy): the percentage found by dividing the useful work obtained from a machine by the total work put into it (p. 155).

***electricity** (e lek tris′i ty): the form of energy appearing in

electrical currents and in electric lighting (p. 373).

***electrify** (e lek'tri fi): to charge with electricity or electrical energy (p. 374).

electrolysis (e lek trol'i sis): the process of separating a substance into its parts by sending through it a direct current of electricity (p. 399).

***electromagnet** (e lek'tro mag'net): a coil of wire which is wound round a core of soft iron and through which electric current is flowing (p. 391).

electromotive force, or E.M.F.: (e lek'tro mo'tiv) the energy which forces electrical currents through conductors; voltage (p. 384).

***electron** (e lek'tron): a negative charge of electricity (p. 376).

***element** (el'e ment): a substance that cannot be broken up into simpler substances (p. 112).

embryo (em'bre o): a plant or animal in its earliest stages of development (p. 586).

***energy** (en'er jy): the capacity for doing work, that is, for moving or making something else move (p. 4).

***environment** (en vi'ron ment): all the surroundings and conditions among which a plant or an animal lives (p. 7).

enzyme (en'zime): a substance which causes changes without itself changing, such as those of digestion or fermentation (p. 606).

***equator** (e kway'tor): the imaginary line round the earth halfway between the north and south poles, where the vertical rays of the sun strike on March 21 and September 22 (p. 304).

equinox (e'kwi noks): the dates March 21 and September 22, when there are twelve hours of daylight and twelve hours of darkness everywhere on the earth (p. 308).

***erosion** (e ro'zhun): the process by which portions of the rock and soil upon and below the earth's surface are scraped or scoured off and carried away by the ground water, running water, winds, glaciers, and ocean currents (p. 329).

***eruption** (e rup'shun): a pouring forth of material, as from a volcano (p. 324).

***esophagus** (e sof'a gus): the part of the food tube, or alimentary canal, leading from the throat to the stomach (p. 606).

evaporation (e vap o ra'shun): the act of changing a liquid or a solid into a vapor by heating it (p. 33).

***evergreen** (ev'er green): a plant that has green leaves throughout the year (p. 677).

excretion (ex kre'shun): the process by which plants and animals get rid of waste materials (p. 608).

***expand** (ex pand'): to swell out, to increase in volume (p. 164).

***expansion** (ex pan'shun): the act of increasing in volume (p. 163).

experimental factor (ex per i men'tal fak'tor): the one and only

condition that is different in two parts of an experiment which are intended to solve the same problem (p. 31).

explosion (ex plo'zhun): the rapid and violent expansion of gases resulting from very rapid oxidation or from the sudden release of pressure (p. 30).

***Fahrenheit** (far'en hite): the scale of a common kind of thermometer on which the freezing point of water is 32 degrees and the boiling point of water is 212 degrees (p. 168).

***fat:** one of the energy foods (p. 638).

***fermentation** (fer men ta'shun): the process by which yeasts and bacteria act upon foods containing sugar to produce alcohol and carbon dioxide (p. 551).

***fertilize** (fer'ti lize): to make fertile for crops; to make capable of reproducing (pp. 362, 585).

***fiber** (fi'ber): a fine thread (p. 207).

***filter** (fil'ter): a porous substance or a device used to remove solid particles from a liquid; to pass through a filter (p. 89).

***food:** a substance required by every plant and animal as a source of energy, body-building materials, or other things needed by the plant or animal (p. 637).

***foot-pound:** the unit of work; a force of 1 pound moving a distance of 1 foot (p. 138).

***force:** a push or a pull (p. 134).

***fossil** (fos'il): the forms or remains of ancient plants or animals preserved in earth or rock (p. 359).

freezing point: the temperature at which a substance, as water, changes from a liquid to the solid state (p. 164).

***frequency** (fre'kwen sy): the number of vibrations made by a body or by an electrical discharge in one second (p. 440).

***friction** (frik'shun): the resistance to the movement of one object upon the surface of another (p. 135).

fulcrum (ful'krum): the point on which a lever pivots or turns (p. 145).

***function** (funk'shun): the special service or duty performed by an organism or by a part of an organism (p. 539).

***fungus** (fun'gus), *plural* **fungi** (fun'ji): the group name for simple plants that do not have chlorophyll (p. 549).

fuse: to melt; also, in electricity, a piece of wire or strip of metal which melts at a relatively low temperature, inserted into an electric circuit for protection in case too much current passes through the circuit (p. 409).

galaxy (gal'ax y): an enormous cluster of suns or stars in the heavens, as the Milky Way (p. 266).

***gaseous** (gas'e us): like a gas or a vapor (p. 111).

***gastric** (gas'trik) **juice:** the name given to the digestive fluids produced in the stomach (p. 606).

gear: a wheel having teeth on the rim and serving to carry motion from one place to another, or to change the rate or the direction of motion (Fig. 104, p. 153).

generator (jen'er a tor): a machine for transforming mechanical energy into electrical energy; a dynamo (p. 394).

germ (jurm): a very small plant or animal parasite which may produce disease (p. 85).

germicide (jur'mi side): a substance, usually a liquid, which kills germs (p. 88).

***germinate** (jur'mi nate): to begin to grow, as from a spore or a seed (p. 660).

***geyser** (gi'zer): a hot spring which spouts boiling water and steam (p. 345).

***glacier** (glay'sher): a river of ice slowly flowing down a valley on a mountainside (p. 333).

***gland:** an organ which produces a special secretion, or kind of body fluid (p. 603).

gradation (gra da'shun): the leveling of the earth's surface resulting from the removal of the soil and the rocks from hills and mountains into the valleys and finally into the oceans (p. 324).

***grafting** (graft'ing): the process of inserting a part of an animal or of a plant in another in such a way that it will grow as part of the second animal or plant (p. 583).

***gravitation** (grav i ta'shun): the attraction which every body has for every other body (p. 122).

***gravity** (grav'i ty): the attraction which every body has for every other body, but especially the force that pulls objects to the earth (p. 122).

grounded circuit (sir'kit): in electricity, a path for the electrical current which is made complete so that the current will flow through it by connecting the wires from both terminals with the earth instead of making the entire path through metal (p. 432).

hard water: water in which compounds of calcium or magnesium or of both are dissolved (p. 94).

***heart:** the organ which forces the blood through the body (p. 602).

***heat:** one of the forms of energy (p. 161).

***heavens** (hev'enz): the sky (p. 267).

***helium** (he'le um): a colorless, inactive gas; one of the rare gaseous elements of the atmosphere (p. 28).

hemoglobin (he mo glo'bin): the coloring matter of the red corpuscles of the blood (p. 612).

***heredity** (he red'i ty): the possession of characters, or characteristics, inherited from ancestors (p. 592).

hibernation (hi ber na'shun): the habit among animals of passing long cold or dry periods in a state of inaction or dormancy (p. 534).

high: an anticyclone, or large area in which the barometric pressure is above the normal atmos-

pheric pressure, that is, above 29.9 inches (p. 228).

horse latitudes: a region between the higher latitudes and the tropics in which calm weather may exist for long periods (Fig. 176, p. 251).

***horsepower:** the unit of power or the speed with which work is done; equal to 33,000 pounds lifted a distance of 1 foot in 1 minute (p. 156).

host: the plant or the animal on which or inside of which a parasite lives (p. 632).

humidity (hu mid'i ty): the water vapor in the air (p. 224).

humus (hu'mus): rich soil produced from the decay of animal and vegetable matter (p. 660).

hydraulic (hi draw'lik): having to do with water (p. 67).

hydrocarbon (hi dro kar'bon): a chemical compound that is composed only of carbon and hydrogen, as petroleum (p. 351).

***hydrochloric** (hi dro klor'ik) **acid:** an acid which is widely used in industry and which also is found in the stomach, where it softens food tissues, kills some bacteria, and partly digests protein (p. 606).

hygiene (hi'ji een): the study of the proper care of the body (p. 606).

hypothesis (hi poth'e sis): a scientist's attempt to tell, after he has been able to secure only part of the facts, what will happen under certain conditions; his attempt to make an explanation which will fit the observed facts (p. 21).

***igneous** (ig'ne us) **rock:** rock that has been melted by volcanism, that is, by the earth's heat (p. 360).

***image** (im'aj): a picture or representation produced by refraction or reflection (p. 459).

immune (i mune'): free from or protected against something, as a disease (p. 624).

immunity (i mu'ni ty): freedom; usually applied to freedom from disease (p. 624).

incandescent (in kan des'ent): white-hot, or glowing with heat (p. 30).

***induction** (in duk'shun): the process of magnetizing iron or steel by bringing it into a magnetic field, that is, near a magnet (p. 372); the process of producing an electrical current in a conductor by moving the conductor in a magnetic field (p. 393).

***inertia** (in er'sha): the property of a body which makes it hard to put in motion when it is not moving, and which, if the body is moving, tends to make it continue to move in the same direction (p. 120).

infect (in fekt'): to transfer germs to wounds or to organisms, with the result that the latter become sick (p. 626).

***inherit** (in her'it): to be born with a characteristic or quality which a parent or a more distant ancestor had (p. 593).

inoculation (in ok u la'shun): act of infecting a plant or an animal with germs or their products (p. 623).

inorganic (in or gan'ik): having to do with material which is not and was never a part of a living thing (p. 109).

instinct (in'stinkt): an activity, such as eating or nest-building, which can be carried on without having been learned (p. 611).

insulator (in'su la tor): any substance through which heat energy will pass by conduction with difficulty; a nonconductor, such as hard rubber or wood (p. 196); any substance through which electricity passes with difficulty (p. 383).

***intestinal** (in tes'ti nal): having to do with the intestines, or lower part of the food tube or digestive system (pp. 86, 606).

***invertebrate** (in ver'te brate): an animal that does not have a skeleton inside its body (p. 563).

***involuntary action** (in vol'un ta ry ak'shun): an action, such as heartbeat, dodging, or swallowing, which is carried on without thought (p. 611).

***iodine** (i'o dine): one of the ninety-two elements; iodine is not a metal and is in the form of purplish-black, needle-like crystals (p. 542).

***iron**: a metal, one of the ninety-two elements (p. 353).

irrigation (ir i ga'shun): watering land for agricultural purposes by artificial means (p. 665).

***kilowatt** (kil'o wot) **hour**: a unit of electrical energy equal to a current of 1 ampere flowing at an E.M.F. of 1 volt for 1 hour (p. 412).

kindling temperature (tem'per a chur), or **kindling point**: the temperature at which a substance begins to burn (p. 174).

***kinetic energy** (kin et'ik en'er jy): the energy possessed by moving bodies (p. 130).

laboratory (lab'o ra to ry): a room where scientific work and experimenting are carried on (p. 5).

***larva** (lar'va), *plural* **larvae** (lar'vee): the wormlike stage of certain insects (p. 564).

***larynx** (lar'inx): the voice-producing organ (p. 429).

latitude (lat'i tude): distance on the earth's surface north or south of the equator (p. 315).

***lava** (lah'va): the liquid materials thrown out of volcanoes (p. 324).

***lens**: a flat piece of glass or other transparent substance which has one or both surfaces curving and which is used to refract light (p. 479).

***lever** (le'ver): a pole or bar used in prying, rolling, or otherwise moving an object (p. 145).

lichen (li'ken): a simple form of plant which grows in gray patches on rocks, trees, and moist soil (p. 335).

***light**: one of the forms of radiant energy (p. 458).

***liver** (liv'er): the largest organ in the body. It causes important changes in the blood and produces bile, an important digestive fluid (p. 606).

loam: soil made up of sand or clay and containing organic matter, that is, plant and animal matter (p. 336).

lodestone (load'stone): a rock which is a natural magnet, that is, which attracts iron and steel (p. 367).

***longitude** (lon'ji tude): distance east or west on the earth's surface, measured from the prime, or zero, meridian, which passes through Greenwich, England (p. 311).

low: a cyclone, or area of low barometric pressure, moving as a slowly whirling body of air across the country from west to east (p. 227).

luminous (lu'mi nus): giving off light, as the sun (p. 458).

lunar (lu'ner): having to do with the moon (p. 290).

***lung:** the organ in which oxygen passes into the blood, and carbon dioxide and water pass out of the blood (p. 603).

***machine** (ma sheen'): a device for doing work.

magnet (mag'net): a piece of iron, steel, or other metal which attracts iron or steel (p. 368).

magnetic (mag net'ik) **field:** the space around a magnet where the magnet can exert force and do work upon iron and steel (Fig. 246, p. 371).

magnetic induction (in duk'shun): the act or process of making a piece of iron or steel into a magnet by merely bringing it near a magnet (p. 372).

***magnetic lines of force:** the invisible lines of magnetic energy around a magnet (p. 371).

***magnetism** (mag'ne tizm): the energy possessed by a magnet (p. 368).

***magnetize** (mag'ne tize): to make into a magnet (p. 368).

***mammal** (mam'al): an animal which produces milk to feed its young (p. 564).

matter (mat'er): the general name given to all substances of every sort; anything that occupies space and has weight (p. 109).

***mechanical** (me kan'i kl): having to do with machines (p. 142).

***mechanical energy** (en'er jy): the energy possessed by moving machinery (p. 142).

melting (mel'ting) **point:** the temperature at which a substance melts (p. 164).

***membrane** (mem'brane): a thin lining or covering (pp. 427, 526).

meridian (me rid'i an): an imaginary line running north and south on the earth's surface and extending from pole to pole (p. 311).

metamorphic (met a mor'fik) **rock:** sedimentary or igneous rock which has been changed by intense heat, pressure, water in the rock, and sometimes by movement (p. 360).

***meteor** (me'te or): a "shooting star"; a mass of stone or of iron which in falling through the atmosphere is burned, leaving for an instant a bright trail (p. 285).

meteorite (me′te o rite): a mass of solid substance which falls through the atmosphere to the earth (p. 286).

microphone (mi′kro fone): a device for receiving and transmitting sound waves (p. 434).

***microscope** (mi′kro skope): an instrument used to make very small objects look larger (p. 485).

migrate (mi′grate): to go to a new habitat, or place of living, in a different region (p. 256).

***mineral** (min′er al): an element or a compound found in the earth (p. 352).

***mirror** (mir′er): an opaque object with a surface smooth enough to reflect the light in such a way as to show an image of objects in front of the surface (p. 459).

***mixture** (mix′chur): the result of putting together two or more substances without changing the nature of any of the substances (p. 113).

molds: a group of small fungus plants (p. 550).

***molecule** (mol′e kule): the smallest unit of a substance (pp. 61, 375).

motor (mo′ter): a machine for transforming the kinetic energy of flowing water or the electrical energy of a current into the mechanical energy of a whirling wheel (p. 397).

***muscle** (mus″l): the tissue which moves one of the parts of the body (p. 601).

natural gas: a fuel secured usually from oil wells or from oil-bearing rock or sand (p. 181).

neap tides: the smallest tides of the month, those which occur at the first and third quarters of the moon (p. 300).

nebula (neb′u la), *plural* **nebulae** (neb′u lee): a mass of gases and pieces of solid matter in space, all collected around a central mass (p. 318).

nectar (nek′ter): the sweet liquid found in many kinds of flowers (p. 568).

***nerve:** one of the body cells which carry to the brain impressions concerning conditions outside the body, or which control movement (p. 610).

***nervous system** (ner′vus sis′tem): all the nerves of the body, including the brain (p. 610).

neutral (nu′tral) **body:** one on which the total positive and negative charges are equal (p. 377).

***neutralize** (nu′tral ize): to make equal the positive and the negative charges on a body (p. 379).

***nitrogen** (ni′tro jen): an inactive gas, which has neither color nor odor, and which makes up about four fifths of the atmosphere (p. 27).

nodule (nod′ule): an enlarged joint or small knot, such as those on a clover root (p. 673).

nonconductor (non kon duk′tor): an insulator; any substance through which electrical currents or conducted heat pass with difficulty (p. 384).

norther (nor′ther): a violent and usually cold wind storm com-

ing from the north or the northwest (p. 230).

***nucleus** (nu'kle us): the central mass in an atom (p. 376); the denser, usually central, part of a living cell (p. 526).

ohm (ome): the unit of electrical resistance (p. 385).

opaque (o pake'): not allowing light to pass through (p. 459).

***optical** (op'ti kl): related to vision, having to do with seeing (p. 484).

***orbit** (or'bit): the path of a heavenly body round a larger body, as the orbit of the moon round the earth (p. 270).

***ore**: a rock containing one or more minerals (p. 353).

***organ** (or'gan): a group of tissues which together perform some special function, as the eye and the heart (p. 525).

organic (or gan'ik): having to do with living or once living material (p. 109).

***organism** (or'gan izm): any living thing; an animal or a plant (p. 32).

***osmosis** (os mo'sis): the passage of a liquid or a gas through a moist membrane from the place where the gas or the liquid is more concentrated to a place where it is less concentrated (p. 527).

***ovary** (o'va ry): in plants, the part of the pistil in which seeds are produced; in animals, the structure in which eggs are formed (p. 584).

***ovule** (o'vule): the structure within the ovary of a plant in which the eggs are formed (p. 584).

oxidation (ox i da'shun): the process by which oxygen combines with some other substance to form a new substance (p. 30).

***oxide** (ox'ide): a substance formed when oxygen combines chemically with another element or with a compound (p. 30).

oxidize (ox'i dize): to combine with oxygen (p. 30).

***oxygen** (ox'i jen): a very active gaseous element which has neither color nor odor and which makes up about one fifth of the atmosphere (p. 27).

pancreas (pan'kre as): a gland producing several digestive enzymes (p. 606).

***parallel of latitude** (par'a lel ov lat'i tude): an imaginary circle running east and west around the earth parallel with the equator (p. 315).

***parasite** (par'a site): a living plant or animal which lives on or inside, but always at the expense of, another plant or animal (p. 554).

partial vacuum (par'shal vak'u um): a space in which the pressure of the air is less than the pressure of the air surrounding the space (p. 22).

pasteurize (pas'ter ize): to retard, or make slower, the action or the multiplication of bacteria in milk, by heating, then cooling, the liquid (p. 649).

penumbra (pe num'bra): the lighter part of a shadow which

surrounds the darker part and which receives some light directly from part of the source (p. 461).

periscope (per'i skope): a device for using mirrors so that one can see around or above solid objects (p. 478).

***perspiration** (per spi ra'shun): moisture given off by the body through the pores of the skin (p. 209).

petal (pet''l): one of the leaflike, usually colored, parts of a flower which surround the pistil (p. 584).

***petrifying** (pet'ri fi ing), or **petrifaction** (pet ri fak'shun): the process by which mineral matter is deposited in place of animal or plant remains, with the result that finally the mineral matter has taken the place and the shape of the animal or plant parts (p. 359).

***petroleum** (pe tro'le um): crude oil that is secured from an oil well (p. 348).

***phases of the moon:** the changes in the appearance of the moon from week to week, as it revolves around the earth (p. 295).

phenomenon (fe nom'e non), *plural* **phenomena:** an occurrence, an observed fact, or a happening (p. 10).

***phosphorus** (fos'fo rus): an active element in the form of a yellow waxlike solid or a red powder (p. 34).

***photosynthesis** (fo to sin'the sis): the process by which green plants use the energy of sunlight to make sugars and starches from carbon dioxide and water (p. 543).

physical (fiz'i kl) **change:** a change in the shape, size, or state of a body without a change in its composition (p. 116).

***physiology** (fiz i ol'o jy): the study of the living processes of plants and animals (p. 610).

pistil (pis'til): the central structure of a flower, which contains the ovary and the ovules (Fig. 394, p. 584).

piston (pis'ton): a disk made to slide back and forth in a cylinder (Fig. 338, p. 495).

***pitch:** in music, the highness or the lowness of a tone, depending on the number of vibrations which the sounding body makes in one second (p. 422).

***planet** (plan'et): one of the nine major satellites of the sun (p. 274).

planetesimal (plan et es'i mal): a small piece of matter in the heavens (p. 320).

planetoid (plan'e toid): an asteroid; one of the small planetlike bodies which revolve round the sun in orbits which are between those of Mars and Jupiter (p. 279).

***pole:** the point farthest north or farthest south on the earth (p. 308); the point on a magnet where the magnetism is centered (p. 370); the terminal of an electrical cell (p. 390).

***pollen** (pol'en): the small bodies which develop in the stamens of flowers, and in which the male cells develop which fer-

tilize the eggs in the ovary of the flower (p. 584).

pollution (po lu'shun): contamination; the act of making impure with disease germs; the material which causes such impurity (p. 86).

***potential** (po ten'shal) **energy:** stored energy, or energy of position or condition (p. 130).

power (pow'er): the rate of doing work (p. 155).

precipitation (pre sip i ta'shun): condensed water vapor falling upon the earth in the form of mist, rain, snow, sleet, or hail, or depositing upon cold objects in the form of dew or frost (p. 235).

***pressure** (presh'er): the force against a square inch or a square foot of surface (p. 21).

***protein** (pro'te in): a complex food such as is contained in meat and eggs (p. 638).

proton (pro'ton): according to the electron theory, one of the positively charged particles which are found in the nucleus of an atom (p. 376).

***protoplasm** (pro'to plazm): the living material of plant and animal cells (p. 525).

Protozoa (pro to zo'a): the group of animals having bodies consisting of only one cell (p. 563).

***quality** (kwol'i ty) **of sound:** the individual differences which distinguish two sounds of the same pitch and loudness (p. 422).

quarantine (kwar'an teen): a law or rule for keeping disease germs or pests from being carried to places that do not have them (p. 671).

***radiant energy** (ra'di ant en'er-jy): the energy which travels through space in straight lines at the rate of about 186,000 miles per second; radiant heat, light, radio waves, and X rays are examples of radiant energy (p. 440).

***radiation** (ra di a'shun): the traveling of heat, light, and other forms of radiant energy through space at a speed of about 186,000 miles per second (p. 192).

***red corpuscle** (kor'pus 'l): one of the disk-shaped cells of the blood, which carry oxygen to the body cells (p. 603).

***reflection** (re flek'shun): the throwing back of light, heat, or sound from a surface (pp. 194, 459).

***reflex** (re'flex), or **reflex action:** a very simple action, such as dodging or swallowing, which is carried on without thought or without having been learned (p. 611).

reforestation (re for es ta'shun): the act of planting forests again upon areas from which the forests have been removed (p. 684).

***refraction** (re frak'shun): the changing of the direction of the rays of light when the light passes from one transparent substance into another of different density (p. 463).

refrigeration (re frij er a′shun): the process of cooling and keeping cool those foods and other substances which might "spoil" (p. 201).

relative humidity (rel′a tiv humid′i ty): the amount of moisture in the air as compared to the amount which the air could hold at the same temperature, expressed in per cent (p. 232).

***reproduce** (re pro duce′): to produce again (p. 487) or to produce young (p. 587).

reproduction (re pro duk′shun): the process of producing new living things (p. 581); the process of producing new sounds, photographs, and the like which resemble the originals (p. 487).

reptile (rep′til): a cold-blooded air-breathing animal having a backbone, and usually having scales, as a snake or a lizard (p. 564).

residual (re zid′u al) **soil:** weathered rock remaining in the place where it weathered (p. 337).

***resistance** (re zis′tance): opposition to motion, action, force, or effort (p. 136); opposition to the flow of electric current (p. 385).

***respiration** (res pi ra′shun): the process by which plants and animals take in oxygen and give off carbon dioxide and water (p. 607).

***revolution** (rev o lu′shun): the act of going round another object, as a planet round the sun (p. 277).

***rock:** a substance found in the earth composed of two or more minerals which are not combined but are mixed in proportions which vary with different samples (p. 352).

***root hair:** one of the very small single cells which grow from the surface of small roots and through which water and dissolved substances enter the root (p. 524).

***rotate** (ro′tate): to spin on an axis, as a top on the ground (p. 271).

***saliva** (sa li′va): a digestive juice which is produced by glands in the mouth and which helps in changing starch to sugar (p. 606).

***salt:** a substance which is formed by combining an acid and a base and which does not change the color of either red or blue litmus paper (p. 111).

sanitation (san i ta′shun): the process of making and keeping places free from filth and from disease germs (p. 104).

saprophyte (sap′ro fite): any plant that lives upon dead organisms (p. 554).

***satellite** (sat′e lite): any heavenly body which revolves round a larger one (p. 275).

saturate (sat′u rate): to fill anything with a substance to the extent that it holds as much of the substance as possible, as a sponge completely full of water (p. 232).

***Saturn** (sat′urn): the sixth planet from the sun; the only planet surrounded by rings (p. 282).

seasons (see'zonz): the changes in weather from one quarter of the year to the next, caused by the tilt of the earth's axis and the shifting of the vertical rays of the sun as the earth revolves round the sun (p. 303).

sediment (sed'i ment): solid or undissolved particles in water or other liquid (p. 89).

***sedimentary** (sed i men'ta ry): formed of sediment, or bits of rock, soil, and organic matter which settle to the bottoms of bodies of water (p. 326).

sedimentary rock: rock formed by the slow hardening and cementing together of layers of sediment which slowly collected in the bottoms of lakes and oceans (p. 358).

***sepal** (se'pal): one of the leaf-like outside flower parts near the base of the pistil of a flower (p. 584).

septic (sep'tik): producing decay through the action of certain kinds of bacteria (p. 101).

***serum** (se'rum): the watery portion of the blood (p. 629).

sewage (su'aj): the waste material which flows from toilets and from streets through pipes called sewers (p. 101).

***shadow** (shad'ow): a space from which part or all of the light has been cut off (p. 461).

short circuit (sir'kit): the passage of an electric current over a path other than the one it was intended to take (p. 410).

siphon (si'fon): a tube through which liquid is forced from a higher to a lower level by air pressure (Fig. 27, p. 46).

***skeleton** (skel'e tun): the supporting frame of a building or of an animal body (Fig. 403, p. 600).

sleet: rain mixed with snow or ice, or rain which freezes while falling or as it strikes the earth (p. 239).

***soil**: decayed rock, usually mixed with humus (p. 335).

***solar** (so'ler): having to do with the sun (p. 265).

solar system: the sun and all the bodies which rotate around the sun (p. 265).

solstice (sol'stis): the dates June 22 and December 22, when the direct rays of the sun strike farthest north or farthest south of the equator (p. 308).

solution (so lu'shun): a liquid in which a solid or a gas has dissolved (pp. 59, 117).

***solvent** (sol'vent): a substance in which another substance dissolves (p. 59).

***sound**: the result when a succession of waves traveling through matter strikes the ear (p. 419).

space: the vacuum which exists among the heavenly bodies (p. 265).

specific gravity (spe sif'ik grav'-i ty): the weight of a body compared with the weight of an equal volume of water (p. 122).

spectroscope (spek'tro skope): an optical instrument having a prism through which light from an incandescent body, as a star, is viewed (Fig. 334, p. 489).

spore: the reproductive body of a nonflowering plant, such as a mold or a fern (Fig. 374, p. 550).

spring tides: the highest tides of the month — those occurring at new moon and full moon (p. 300).

stability (sta bil'i ty): the state of being firm or steady, so as not to be easily upset (p. 513).

***stamen** (sta'men): the part of the flower which produces the pollen in which the male reproductive cells develop (p. 584).

***standard time:** uniform time throughout all parts of a belt about fifteen degrees wide (p. 312).

***star:** a sun; an incandescent heavenly body which keeps its same relative position from year to year (p. 265).

***static** (stat'ik) **electricity:** electrical energy which is not flowing as a current (p. 374).

***steam:** water in the form of an invisible vapor (p. 62).

***stomach** (stum'ak): the organ which receives food from the mouth and partly digests it (p. 606).

***stratum** (stra'tum), *plural* **strata** (stra'ta): a layer; the word is especially applied to rocks, soil, or clouds (pp. 73, 237, 324).

submarine (sub ma reen'): a boat which can operate beneath the water's surface (p. 125).

suction (suk'shun): when a pressure forces something toward or into a partial vacuum, the process is called suction (p. 41).

***sulfur** (sul'fur): one of the ninety-two elements. It is a nonmetal and is ordinarily in the form of a yellow powder or of blunt yellow crystals (p. 608).

***sun:** a star; an incandescent heavenly body which keeps its same relative position from year to year (p. 266).

sun time: the exact hour of the day as measured by the sun, at any point on the earth (p. 311).

***sunspot:** a violent storm on the surface of the sun (p. 272).

suture (su'chur): a joint formed by bones fitted together like the teeth of two saws or like the wooden edges of a dresser drawer (p. 601).

switch: an appliance for breaking and for completing an electrical circuit (p. 408).

synthesis (sin'the sis): the process of building a substance by combining elements or compounds (p. 117).

***telescope** (tel'e skope): an optical instrument used to study objects, such as stars and planets, which are too far away to be seen clearly with the naked eye (p. 486).

television (tel e vizh'un): the transmission of both sound and images by ether waves (p. 451).

***temperature** (tem'per a chur): the measure of how intense or how low the heat is (p. 166).

tendon (ten'don): the strong cordlike end of a muscle by

which it is attached to a bone (p. 602).

terminal (ter'mi nal): in electricity, one of the poles or metal parts of a cell, or other electrical device, to which the wires are connected (p. 390).

terrestrial (te res'tri al) **planets:** the four smaller planets nearest the sun (p. 275).

***thermometer** (ther mom'e ter): a device for measuring the heat (p. 167).

***tidal** (ti'dl): having to do with the tides (p. 301).

***tides:** the rise and fall of water on the shores of the ocean and the great lakes because of the attraction of the moon and the sun (p. 299).

***tissue** (tish'u): a group of cells of the same kind, serving the same function (p. 525).

tornado (tor na'do): a type of small, violently whirling, and very destructive wind (p. 228).

***toxin** (tox'in): a poisonous substance produced by disease germs during their growth (p. 628).

transformer (trans form'er): in electricity, a device for increasing or decreasing the E.M.F., or voltage, of an alternating current in a circuit (p. 404).

translucent (trans lu'sent): allowing some light to pass through but not entirely transparent (p. 459).

***transparent** (trans par'ent): allowing light to pass through so that an object can be seen clearly through the substance (p. 459).

transpiration (tran spi ra'shun): the evaporation of water from the surfaces of plants into the air (p. 541).

turbine (tur'bin): a special type of power wheel turned by water or steam (pp. 70, 497).

umbra (um'bra): the part of a shadow which receives no direct light from the source of light (Fig. 311, p. 461).

***Uranus** (u'ra nus): the seventh planet from the sun (p. 283).

urine (u'rin): the fluid waste material taken from the blood by the kidneys and stored in the bladder until its removal (p. 608).

vaccination (vak si na'shun): the process of inducing a mild form of disease by use of weakened or dead germs or of the products from these germs (p. 623).

vacuum (vak'u um): a space that contains nothing whatever (p. 22).

valve: a device within a pipe or a tube by means of which a passage is closed or opened (Fig. 26, p. 45).

***vaporize** (va'per ize): to change into a vapor (p. 111).

***variation** (va ri a'shun): a difference from the parents in structure or function (p. 590).

vegetation (vej e ta'shun): plant life of any sort (p. 256).

vein: one of the blood vessels through which blood returns

from the capillaries to the heart (p. 603).

ventilation (ven ti la′shun): provision for free circulation of air (p. 198).

*__vertebra__ (ver′te bra): one of the bones composing the spinal column (p. 609).

*__vertebrates__ (ver′te brates): the large group of animals which have a spinal column serving as the main support of the body (p. 564).

*__vibrate__ (vi′brate): to move to and fro, as the wings of a buzzing insect (p. 419).

*__vitamin__ (vi′ta min): one of a group of non-energy foods necessary to health and normal development (p. 644).

volcanism (vol′kan izm): the process producing changes in the surface of the earth due to the effects of heat within the earth (p. 323).

*__volcano__ (vol ka′no): a chimney-like opening in the earth, from which issue molten rock, dust, or gases, or all of these (p. 324).

*__volt__: the unit of E.M.F., or voltage (p. 384).

voltage (vol′taj): the E.M.F., or electromotive force; the form of electrical energy which forces a current through a conductor (p. 384).

*__voluntary action__ (vol′un ta ry ak′shun): an activity which cannot be carried on without thought, such as throwing a ball, changing an automobile tire, or building a radio set (p. 610).

water cycle (si′kl): the endless succession of changes from water to water vapor and then from water vapor to rain or other forms of precipitation (p. 242).

water table: the top level of the ground water (p. 74).

*__water vapor__ (va′per): water in the gaseous state (p. 62).

*__watt__ (wŏt): a unit of power, equal to a current of 1 ampere flowing at an E.M.F. of 1 volt for 1 hour (p. 412).

*__weather__ (weth′er): the day-to-day changes with respect to air pressure, humidity, rainfall, clouds, sunshine, and the winds (p. 249)

*__weathering__: the process of breaking and changing rock into soil (p. 329).

wind: a current of air, caused by differences in atmospheric pressure (p. 198).

work: the effect or result of moving a body (p. 134).

yeasts: a group of single-celled fungus plants (p. 551).

zero meridian (me rid′i an): the meridian of longitude which passes through Greenwich, England, and which is used as the starting point for the numbering of the meridians (p. 311).

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